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DEMONSTRATED TECHNOLOGY AND RESEARCH NEEDS FOR REUSE OF MUNICIPAL WASTEWATER

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16. ABSTRACT

This survey identified 358 sites at which direct reuse of municipal wastewater was being practiced. Detailed data were gathered on volume, effluent quality, treatment, reliability and economics.

It was found that direct reuse of municipal wastewater was not widespread accounting for less than 2 per cent of this nation's water use in 1972. Irrigation and industrial cooling account for virtually all of this reuse. Only three sites practice reuse for recreational lakes, and one for nonpotable domestic use. Potable reuse is not presently practiced. General quality standards could not be derived for any category. In fact, water which is substandard according to published criteria is being successfully used in many reuse situations by fitting the water quality to the specific local condition. Overall economic analysis was also difficult. Storage and distance between supplier and consumer were more important considerations than quality and treatment. In general, the supplier undercharged the consumer because reuse was viewed as an inexpensive disposal technique.

There is significant potential for an increase in reuse of wastewater in all categories; increased publicity concerning successful reuse is required to initiate this increase.

17. KEY WORDS AND DOCUMENT ANALYSIS

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment - air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

The ever increasing demands for fresh water combined with a limited supply has made the renovation and reuse of wastewater an important component of water resource planning. This study presents the results of a survey of existing reuse of municipal wastewater in the United States of America. Reuse categories covered included agricultural and industrial, recreational and domestic.

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National Environmental
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SECTION I

SCOPE, OBJECTIVES, AND APPROACH

SCOPE

This study was limited to reuse of wastewater from municipal plants with emphasis upon direct reuse of the water as it leaves the treatment plant. Projects involving indirect reuse after injection or percolation were not included except where the degree of dilution by groundwater is slight. Similarly, projects were not included which involved indirect reuse by downstream withdrawal of surface waters containing wastewater, unless the degree of dilution with natural surface waters is slight. Industrial reuse of in-plant water is not included.

The types of reuse covered in this study are:

- Irrigation and other agricultural uses
- Cooling water
- Industrial process water
- Boiler feed water
- Recreational lakes
- Fish propagation
- Non-potable domestic use

OBJECTIVES

The primary purpose of this study was to make a state-of-the-art survey to bring together information about existing reuse operations in a concise form. This information can be used by design engineers in the design of new reuse systems and by governmental decision makers in planning whether such systems are appropriate to their situations. The report is also a useful tool for responsible management and technical personnel in locating existing reuse operations which can provide valuable background experience. A second purpose of the project is to spotlight deficiencies that exist in the available reuse information and suggest future research to overcome these deficiencies.

Specific project objectives were as follows:

- Conduct a literature search to collect data on those projects for which publications exist, and also to obtain water quality criteria for various reuse applications.
- Supplement the literature search by various means to locate and obtain descriptive information on unpublicized municipal reuse projects and update existing information on publicized projects.
- Conduct field investigations of important municipal reuse operations which are relatively little known. Well-documented operations, e.g., Santee, California; Lake Tahoe, California; etc., were not visited.
- For each reuse situation obtain technical and economic information pertinent to size, design, performance, costs, reuse application, and problems.
- Organize and analyze the data in an attempt to arrive at optimum treatment systems and values of design parameters which can be recommended for specific reuse applications.

APPROACH

The following tasks were performed by the SCS Engineers project team during the completion of this study:

- A comprehensive literature search was conducted in the Library of Congress, several large university libraries, and EPA in-house sources for any information pertinent to municipal wastewater reuse operations. Hundreds of sources were reviewed (see Bibliography, Section VIII)and information extracted. With the exception of the highly publicized reuse projects, most of the published literature was out of date and incomplete.
- Letters were written requesting assistance in locating municipal wastewater reuse projects to the following organizations:
  - All 50 state water pollution control regulatory agencies.
  - Each of the 59 U.S. and foreign member associations of the Water Pollution Control Federation.

- Each of the 51 State Water Resource Research Institutes.

- Various Federal agencies including the Bureau of Reclamation, Office of Water Resources Research, and several divisions within the Environmental Protection Agency.

- Prominent consulting engineering firms active in pollution control facility design, including all those placing professional service cards in the Journal of the Water Pollution Control Association.

- University-connected individuals who have published reports related to wastewater reuse.

- The national agencies responsible for pollution control in all of the Major European Countries, plus Russia, Japan, Israel, Canada, Mexico, and Australia.

Follow-up letter and telephone calls were made to corresponding state agencies until answers were received from all.

.. A total of 358 United States and 55 foreign reuse sites were tentatively identified. Of the 358 U.S. sites, 205 were judged to be very small irrigation disposal operations. A detailed 11 page questionnaire (See Appendix G) was prepared and sent to the 153 other American sites and 55 foreign sites. U.S. respondents totaled 145. Foreign response was poor throughout the project, finally totaling only 6 out of 55 questionnaires sent.

. In cooperation with the EPA Project Officer, 18 of the most unique, little known reuse operations were selected for field investigation and case studies prepared (see Appendix A). The case studies included examples of reuse for irrigation of crops for human consumption, irrigation of crops not for human consumption, industrial reuse, recreational lakes, and non-potable domestic use (i.e., toilet flushing).

. A summary tabulation was made (see Appendix B) of data received from U.S. questionnaire respondents. The tabulation concisely presents data pertinent to location, volume, effluent quality, costs, system reliability, plant design, purpose of reuse, and additional treatment by user.

- Separate chapters were prepared describing the results of the study by category of reuse; i.e., irrigation, industrial, recreation, fish propagation, and domestic. Each chapter contains sections covering water quality criteria for the specific reuse, a listing and analysis of existing operations supplying wastewater for the specific reuse, and economic analysis.

SECTION II

IRRIGATION REUSE

INTRODUCTION

Responses to this survey indicated the total yearly reuse volume in this country was 133 billion gallons in 1971. Of this total, 77 billion gallons or 58% was utilized in agriculture. One hundred thirty-two plants answering questionnaires practice irrigation reuse of their effluent. An additional 205 plants in Texas, California, and Arizona irrigate on a very small scale with reclaimed effluent. These small plants locations and associated flows are tabulated in Appendix C, and are not included in the remaining data in the chapter.

Figure 1 shows the increase in irrigational reuse of municipal wastewater during this century, as determined by the year in which the plants surveyed began reuse.

This chapter is divided into three sections, as follows:

- Required water quality, which is largely derived from existing literature sources.
- Analysis of current reuse for irrigation, which is largely derived from the data developed during this study.
- Analysis of current economics, which is largely derived from data developed during this study.

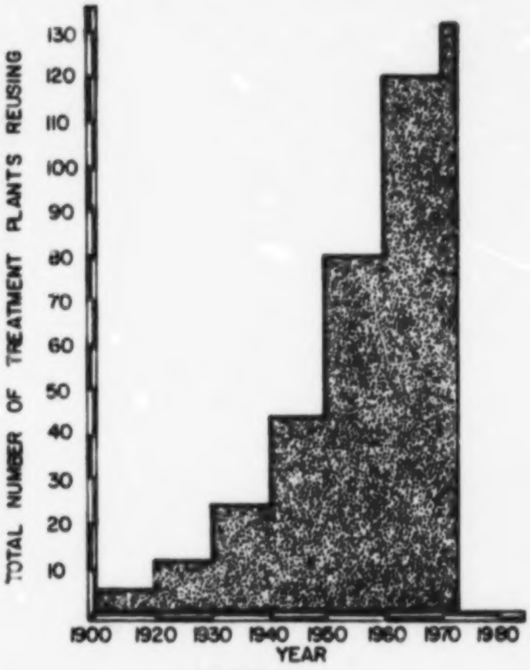

FIGURE I

GROWTH OF IRRIGATION REUSE

REQUIRED QUALITY CRITERIA

General

Irrigation uses can be separated into the following major application subsections:

- Agricultural crops
- Pasture land
- Turf and landscape
- Stock watering

Agricultural Crops and Pasture Land Irrigation

Irrigation water quality is set by a number of factors including short-term effects on crop quality, long-term effect on soil characteristics and the potential effect on the intended utility of the crop. Table 1 presents general limits for irrigation water constituents as suggested by the U.S. EPA.

Irrigation water quality can, however, be assessed only in relation to the specific conditions under which the water is to be used. Absolute limits to the permissible concentrations of salts and constituents in irrigation water are difficult to fix for several reasons: (1) Soil solution is normally three to eight times as concentrated as the irrigating water applied to it because of the evaporation of water from the soil surface, the transpiration of plants, and the selective absorption of mineral constituents by the plants; (2) Plants vary widely in their tolerance to salinity, as well as specific salt constituents; and (3) Soil type, climatic conditions, irrigation practices, and drainage all influence the reaction of a given crop to irrigation water quality. The suitability of a given irrigation water is contingent, therefore, upon both the crop and the soil characteristics. (4)

For example, establishment of a limit for heavy metal elements in irrigation water is complicated by the ability of certain soils and soil conditions to fix and absorb them. Soils containing larger percentages of minerals and/or having high clay contents (fine textured soils) have greater affinity for storing metallic ions than sandy soils. Either soil type, however, shows increased abilities to retain heavy metals at pH levels above 7.0 (alkaline conditions). (6)

Table 1. LIMITS OF POLLUTANTS FOR IRRIGATION WATER RECOMMENDED BY EPA (11)

CONSTITUENTS	FOR WATER USED CONTINUOUSLY ON ALL SOILS (mg/l)	FOR SHORT-TERM USE** ON FINE TEXTURED NEUTRAL AND ALKALINE SOILS (mg/l)
Heavy Metals		
Aluminum	5.0	20.0
Arsenic	2.0	10.0
Beryllium	0.1	0.5
Boron	0.75	2.0
Cadmium	0.01	0.05
Chromium	0.1	1.0
Cobalt	0.05	5.0
Copper	0.2	5.0
Fluoride	2.0	15.0
Iron	5.0	20.0
Lead	5.0	10.0
Lithium	2.5	-
Manganese	0.2	10.0
Molybdenum	0.01	0.05
Nickel	0.2	2.0
Selenium	0.02	-
Bacterial		
Coliform density	1,000/100ml	
Chemical		
pH	4.5-9.0	
TDS	5,000	
Herbicides		
Dalapon	0.2 μg/l	
TCA	0.2 μg/l	
2,4-D	0.1 μg/l	

**"Short-term" used here means a period of time as long as 20 years.

A recent study, (13) compared the effects of continued use, over a 14 year study period, of wastewater effluent and well water as a source of irrigation water on selected soil properties. The results are summarized in Table 2 below.

Table 2. RESULTS OF SOIL TESTS MADE ON GRABE SILT LOAM SOIL (1969)* (13)

Irr. source	Soil hor.	Soluble salts (EC.X10^3)	NO_3 (mg/l)	PO_4 (mg/l)	Modulus of rupture (g)	Infil. rate (cm/hr)
Effluent	Ap	1.77	132	37	223	1.52
	C	0.80	38	16	168	
Well water	Ap	0.88	65	17	137	1.91
	C	0.43	12	8	153	

KEY: Ap horizon (plow layer, 0 to 25 cm)
C horizon (sub-soil, 38 to 51 cm)

As can be seen, soil irrigated with treatment plant effluent had a lower infiltration rate, higher modulus of rupture, and a higher concentration of soluble salts, nitrates, and phosphates than soil irrigated with well water. Thus improperly managed long-term use of irrigation waters (particularly reclaimed wastewater) may result in deterioration of surface soil structure, increased power needs for plowing and tilling, and possible adverse effects on crop growth due to high salt concentrations in the soil. It should be noted, however, that this study(13) indicated that irrigation with wastewater effluent for 14 years had no adverse effect on crop production.

Table 3, on the following page, judges irrigation water quality by the analysis of five basic constituents, % sodium, TDS, boron, chloride and sulfate. Excessive TDS in irrigation water can have an osmotic effect by restricting or preventing water uptake by the crops; the salts can be toxic to plant metabolism, and, by altering soil structure, permeability, and aeration, adversely affect plant growth. (7)

The cations calcium, sodium, and potassium, and the anions, carbonate, bicarbonate, sulfate, chloride, nitrate and phosphate, although essential for plant growth, may be toxic above certain concentrations and are augmented in importance by their effects upon the character of the soil.(2)

Table 3. CRITERION FOR CLASSIFICATION OF IRRIGATION WATERS(4)

Parameter	Classification*				
	Suitable		Marginal		Unsuitable
	Low	High	Low	High	
Na, %**	0	60	60	75	75
TDS, mg/l	0	700	700	2,100	2,100
Boron, mg/l (Semi-tolerant plants)	0	0.5	0.5	2.0	2.0
Chloride, mg/l	0	177	177	355	355
SO_4, mg/l	0	960	960	1,920	1,920

*Classifications apply to most plants under most conditions of soil, climate, and irrigation practices.

**Calculated by: $\frac{(Na)}{(Na + Ca + Mg + K)} \times 100$

Sodium is generally one of the most critical of these ions since it can limit plant growth by increasing the soil alkalinity to deleterious levels. High sodium can also displace calcium and magnesium from the soil, resulting in poor tilth and low permeability of the soil.(2)

Note that the standards given in Table 3 present a range of acceptable concentrations, thus recognizing the varying salt tolerance between different species of plants. Table 4 provides information on relative salt tolerances of selected crops. Since the soil solution is always more concentrated than the irrigation water, the standards for ion concentrations allow for greater limiting values for ions as measured in soil solutions rather than water solution.(4) In addition, crops vary in their sensitivity to various constituents of water as mentioned above. Table 5 provides data on tolerances of selected crops to concentrations of chloride in the soil solution.

Table 4. RELATIVE TOLERANCES OF CROPS TO SALT CONCENTRATIONS (7)

CROP DIVISION	LOW SALT TOLERANCE	MEDIUM SALT TOLERANCE	HIGH SALT TOLERANCE
Fruit Crops	EC x 10^3 ≤ 2 Avacado Lemon Strawberry Peach Apricot Almond Plum Prune Grapefruit Orange Apple Pear	Cantaloupe Grape Olive Fig Pomegranate	Date palm
Vegetable Crops	EC x 10^3 = 3 Green beans Celery Radish EC x 10^3 = 4	EC x 10^3 = 4 Cucumber Squash Peas Onion Carrot Potatoes Sweet corn Lettuce Cauliflower Bell pepper Cabbage Broccoli Tomato EC x 10^3 = 10	EC x 10^3 = 10 Spinach Asparagus Kale Garden beets EC x 10^3 = 12
Forage Crops	EC x 10^3 = 2 Burnet Ladino clover Red clover Alsike clover Meadow foxtail	EC x 10^3 = 4 Sickle milkvetch Sour clover Cicer milkvetch Tall meadow oat-grass Smooth brome Big trefoil Reed canary Meadow fescue Blue grama	EC x 10^3 = 12 Bird's-foot trefoil Barley (hay) Western wheat grass Canada wild rye Rescue grass Rhodes grass

Table 4. (Continued)

CROP DIVISION	LOW SALT TOLERANCE	MEDIUM SALT TOLERANCE		HIGH SALT TOLERANCE
Forage Crops Cont.	White Dutch clover EC x 10^3 = 4	Orchard grass Oats (hay) Wheat (hay) Rye (hay) Tall fescue Alfalfa Hubam clover Sudan grass	Dallis grass Strawberry clover Mountain brome Rye grass Yellow sweetclover White sweetclover EC x 10^3 = 12	Bermuda grass Nuttall alkali grass Salt grass Alkali sacaton EC x 10^3 = 18
Field Crops	EC x 10^3 = 4 Field beans	EC x 10^3 = 6 Castorbeans Sunflower Flax Corn (field) Sorghum	Rice Oats (grain) Wheat (grain) Rye (grain) EC x 10^3 = 10	EC x 10^3 = 10 Cotton Rape Sugar beet Barley (grain) EC x 10^3 = 16

Note: Electrical conductivity (EC) values represent salinity levels at which a 50 percent decrease in yield may be expected as compared to yields on nonsaline soil under comparable growing conditions.

Table 5. MAXIMUM PERMISSIBLE CHLORINE CONTENT IN SOIL SOLUTION FOR SELECTED CROPS(1)

Crop	Rootstock or variety	Limit of tolerance to chloride in soil solution, meq/liter
Citrus	Rangpar lime, Cleopatra mandarin	50
	Rough lemon, tangelo, sour orange	30
	Sweet orange, citrange	20
Stone fruit	Marianna	50
	Lovell, Shalil	20
	Yunnan	14
Avocado	West Indian	16
	Mexican	10
Grape	Varieties	
	Thompson seedless, Perlette	50
	Cardinal, black rose	20
Berries	Boysenberry	20
	Olailie blackberry	20
	Indian summer raspberry	10
Strawberry	Lassen	16
	Shasta	10

Detailed studies have compiled extensive data on the element Boron in irrigation water. Table 6 lists permissible limits and associated crop types which can tolerate these limits.

The allowable bacterial content of irrigation water varies widely depending upon the crop and regulatory agency requirements in various states, as described in the next section of this chapter. In 1968, the FWPCA recommended the following guidelines for irrigation water bacteria counts. This criteria was expressed as particularly applicable to crops destined for direct human or animal consumption:(3)

"The monthly arithmetic average density of the coliform group of bacteria shall not exceed 5,000 per 100 ml, and the monthly arithmetic average density of fecal coliforms shall

Table 6. LIMITS OF BORON IN IRRIGATION WATER(8)

A. PERMISSIBLE LIMITS (mg/l)

CLASS OF WATER	CROP GROUP		
	SENSITIVE	SEMITOLERANT	TOLERANT
Excellent	<0.33	<0.67	<1.00
Good	0.33 to 0.67	0.67 to 1.33	1.00 to 2.00
Permissible	0.67 to 1.00	1.33 to 2.00	2.00 to 3.00
Doubtful	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
Unsuitable	>1.25	>2.50	>3.75

B. CROP GROUPS OF BORON TOLERANCE*

SENSITIVE	SEMITOLERANT	TOLERANT
Pecan	Sunflower	Athel
Walnut	Potato	Asparagus
Jerusalem-artichoke	Cotton	Palm
Navy bean	Tomato	Date palm
American elm	Sweetpea	Sugar beet
Plum	Radish	Mangel
Pear	Field pea	Garden beet
Apple	Ragged Robin rose	Alfalfa
Grape	Olive	Gladiolus
Kadota fig	Barley	Broadbean
Persimmon	Wheat	Onion
Cherry	Corn	Turnip
Peach	Milo	Cabbage
Apricot	Oat	Lettuce
Thornless blackberry	Zinnia	Carrot
Orange	Pumpkin	
Avacado	Bell pepper	
Grapefruit	Sweet potato	
Lemon	Lima bean	

*In each group, the plants first named are considered as being more tolerant; the last named, more sensitive.

not exceed 1,000 per 100 ml. Both of these limits shall be an average of at least two consecutive samples examined per month during the irrigation season. Any one sample examined in any one month shall not exceed a coliform group density of more than 20,000 per 100 ml."

Turf and Landscape Irrigation

In general, golf course turf and hardy vegetation, such as bushes and trees, are more tolerant than agricultural crops to harmful constituents possibly contained in treated wastewater. (An example of both golf course and freeway landscape irrigation is detailed in the field investigation of San Bernardino, California in Appendix A).

Percent sodium in the range of 50-75 percent can be harmful as high percentage sodium water will cause soils to seal, reducing percolation rates, and interfering with root growth. TDS should not exceed 2,500-3,000 ppm. Although no disease transmission has been reported as a result of golf course irrigation with sewage effluent, California standards require that such water be chlorinated to bring the coliform count down to a median MPN of 23 per 100 ml. No adverse effects on greens and fairways is reported unless an excessively high chlorine dosage is substituted for adequate contact time. Over-chlorination will result in bleaching and yellow streaking of the turf.(10)

FIGURE 2

RECLAIMED WASTEWATER IS USED FOR IRRIGATION OF MANY GOLF COURSES

Stock Watering

Although much research data has been accumulated in the U.S. relative to the effects of water-borne constituents on laboratory animals, relatively little information is available on this subject applicable to livestock.(4)

The daily water consumption by animals (See Table 7) determines the total quantities of ingested substances and, thus, the critical limits for animal metabolisms. The daily water volume requirements, however, vary with regard to climate, water content of food consumed, degree of exertion, and salinity of the available water supply.(2)

Table 7. AVERAGE WATER CONSUMPTION FOR SELECTED ANIMALS(2)

Animal	Water consumption in gpd/head
Beef cattle	7-12
Dairy cattle	10-16
Horses	8-12
Swine	3-5
Sheep and goats	1-4
Chickens	8-10 (per 100 birds)
Turkeys	10-15 (per 100 birds)

The tolerance of animals to salts in drinking water depends on several independent factors, including their species, ages, physiological conditions, season of the year, and salt content of foods consumed. Water containing a high concentration of salts may cause gastroenteritis, wasting disease, and death.(4) Lactation and reproduction are usually the first animal functions to be affected by unfavorable mineral concentrations; reduction and termination of milk and eggs production has been observed. Although animals can usually tolerate higher salinity than man, it has been recommended that, for good production, animals should be provided with drinking water of as high a quality as that required for human conumption.(8)

The Department of Agriculture in Western Australia has published the threshold concentrations of salinity at which animals begin to show deleterious symptoms. Table 8 tabulates that government's findings.

Table 8. SALINITY LEVELS TOLERABLE
BY SELECTED ANIMALS (4)

Animal	Threshold salinity (mg/l)
Beef cattle	10,000
Dairy cattle	7,150
Horses	6,435
Pigs	4,290
Adult dry sheep	12,900
Poultry	2,860

Table 9 tabulates threshold and limiting concentrations for various parameters in livestock drinking water.(4) Ionic constituents of water, appear to produce an osmotic effect when present in heavy concentrations. Results from tests have shown that it is this effect rather than the toxicity of any one element that is generally harmful to the animal. Some elements, however, are injurious even in trace concentrations; the most critical of these are nitrates, fluorides, selenium, and molybdenum.(4)

Bacterial infection of livestock by polluted water has not been established even when human disease organisms were detected in the water supply. Experts have recommended, however, that pending further studies and analyses, sewage effluents should be adequately disinfected prior to use by livestock.(4)

ANALYSIS OF CURRENT REUSE FOR IRRIGATION

Table 10 presents an inventory of treatment plants categorized by specific irrigation reuses. This table may be used in conjunction with Appendix B to obtain data pertinent to irrigation of particular crops with municipal wastewater. For example, only one facility is listed as irrigating asparagus, i.e., CA-31, which is found in Appendix B to be the Irvine Ranch Water District, Irvine, California. Appendix B provides additional current information pertinent to water quality, treatment, charges, etc. at the Irvine reuse operation.

Table 9. WATER QUALITY PARAMETER LIMITS FOR LIVESTOCK(4)

Quality factor	Threshold concen.*	Limiting concen.**	EPA acceptable concen.(11)
Total dissolved solids (TDS), mg/l	2,500	5,000	
Cadmium, mg/l	5		5.0
Calcium, mg/l	500	1,000	
Magnesium, mg/l	250	500#	
Sodium, mg/l	1,000	2,000#	
Arsenic, mg/l	1		0.2
Bicarbonate, mg/l	500	500	
Chloride, mg/l	1,500	3,000	
Fluoride, mg/l	1	6	2
Nitrate, mg/l	200	400	100
Nitrite, mg/l	None	None	
Sulfate, mg/l	500	1,000#	
Range of pH	6.0-8.5	5.6-9.0	

*Threshold values represent concentrations at which poultry or sensitive animals might show slight effects from prolonged use of such water. Lower concentrations are of little or no concern.

**Limiting concentrations based on interim criteria, South Africa. Animals in lactation or production might show definite adverse reactions.

#Total magnesium compounds plus sodium sulfate should not exceed 50 percent of the total dissolved solids.

Table 10. INVENTORY OF TREATMENT FACILITIES CATEGORIZED BY SPECIFIC IRRIGATION USES

TYPE OF USE	FACILITY CODE(*)			
RECREATION				
Athletic Fields	AZ-6	CA-63	CO-2	FL-1
Duck Clubs	CA-78			
Game Refuges	AZ-12			
Golf Courses	AZ-3	AZ-5	AZ-8	AZ-13
	AZ-16	AZ-17	CA-13	CA-25
	CA-34	CA-35	CA-36	CA-38
	CA-50	CA-55	CA-56	CA-62
	CA-63	CA-70	CA-74	CO-1
	CO-5	CO-6	ID-1	MO-2
	NM-5	NM-7	NV-2	NV-3
	TX-7	TX-10		
Parks	CA-60	CO-2		
Parade Grounds	AZ-5			
CROPS				
Alfalfa	AZ-4	AZ-14	CA-1	CA-2
	CA-4	CA-5	CA-9	CA-14
	CA-19	CA-23	CA-24	CA-33
	CA-36	CA-40	CA-41	CA-46
	CA-64	CA-67	CA-68	CA-71
	CA-76	ND-1	NM-1	NM-8
	NV-1	NV-2	NV-3	NV-4
	TX-2	TX-6	TX-11	UT-1
Asparagus	CA-31			

*See Appendix B for facility names and specific data.

Table 10. (Continued)

TYPE OF USE	FACILITY CODE(*)			
Avocados	CA-22			
Barley	CA-3	CA-4	CA-5	CA-28
	CA-45	CA-47	CA-75	CA-76
	NV-2	WA-2		
Beans	CA-12	WA-2		
Carrots	WA-1			
Citrus Crops	CA-21	CA-22	CA-31	CA-41
	CA-66			
Corn	CA-4	CA-5	CA-14	CA-23
	CA-24	CA-28	CA-31	CA-45
	CA-64	FL-2	NE-1	
Cotton	AZ-4	AZ-15	CA-1	CA-2
	CA-3	CA-4	CA-5	CA-7
	CA-18	CA-19	CA-20	CA-21
	CA-23	CA-24	CA-28	CA-30
	CA-33	CA-46	CA-64	CA-71
	CA-75	CA-76	NM-1	NM-8
	TX-6			
Cucumbers	CA-36			
Fodder	AZ-12	CA-6	CA-22	CA-29
	CA-48	CA-71		
Forest	MO-1			
Grain	AZ-4	CA-18	CA-20	CA-46
	NM-2	NM-3	NM-6	
Grapes	CA-2	CA-18	CA-23	CA-24
	OR-1	TX-2		

*See Appendix B for facility names and specific data.

Table 10. (Continued)

TYPE OF USE	FACILITY CODE(*)			
Grass	AZ-6	AZ-9	CA-54	CA-63
	CO-3	FL-2	MI-1	OK-2
	TX-11	UT-1		
Hay	CA-19	CA-53	CA-68	NM-9
	NV-1	TX-2		
Landscapes	AZ-6	AZ-14	CA-39	CA-41
	CA-55	CA-72	CO-3	FL-1
Milo Maize	CA-19	CA-45	CA-64	NE-1
	TX-11			
Oats	CA-45	TX-2	TX-11	
Olives	CA-17			
Onions	WA-1			
Pasture	AZ-7	AZ-15	AZ-17	CA-4
	CA-5	CA-6	CA-9	CA-15
	CA-16	CA-18	CA-26	CA-27
	CA-29	CA-30	CA-32	CA-37
	CA-41	CA-47	CA-48	CA-49
	CA-51	CA-52	CA-59	CA-61
	CA-66	CA-73	CA-77	CA-78
	NM-10	NV-2	NV-4	TX-5
	TX-6	TX-12	WA-1	
Potatoes	WA-2			
Rye	CA-47			
Seed	CA-7	CA-44		
Sorghum	AZ-9	CA-17	CA-54	FL-2
	NV-2	TX-6		

*See Appendix B for facility names and specific data.

Table 10. (Continued)

TYPE OF USE	FACILITY CODE(*)
Spinach	WA-1
Squash	CA-36
Sudan Grass	CA-48 CA-54
Sugar Beets	CA-12 CA-36 WA-2
Tomatoes	CA-31
Trees	AZ-6 CA-39 CA-41 CA-63 CO-3 FL-1
Wheat	CA-2 CA-4 CA-5 CA-45 NM-2 NM-6 TX-2 WA-2

*See Appendix B for facility names and specific data.

As shown in Table 11, some treatment plants producing irrigation water report significant percentages of industrial wastes in their influent. Specific industrial wastes reported as being significant are shown in Table 12.

Table 11. PRESENCE OF INDUSTRIAL WASTES IN INFLUENT RAW SEWAGE REUSED FOR IRRIGATION

Average influent industrial waste as % of total influent	Number of treatment plants affected	Percent of treatment plants affected
0	58	46
1 - 10	38	30
11 - 20	17	14
21 - 30	6	5
over 30	6	5

Conventional primary and secondary treatment are not effective in removing certain industrial waste constituents, e.g. boron. Since tertiary plants are generally uneconomical for wastewaters treated specifically for irrigation, it is important to know the sources and types of industrial wastes. Such foreknowledge may determine the type of crop selected or restrictions on certain industrial waste characteristics.

Table 13 tabulates wastewater irrigation into eight major categories of crops and the degree of treatment provided. Approximately three-fourths of the effluent undergoes secondary treatment.

It is surprising, however, that primary treated effluent is still used somewhere to irrigate each of the crop categories. The most significant reuse of primary effluent is for corn, cotton and cattle grazing uses; however, it should be emphasized that this corn is utilized only for cattle feed. This reuse of primary effluent is exemplified by Bakersfield, California (CA-4), described in detail in Appendix A, Field Investigation reports. Two plants (CA-2 and CA-23) within the vegetable and fruit categories provide primary effluent for irrigation of grape vineyards and olive groves.

Fifteen plants supply tertiary water for irrigation; one unique example of such tertiary treatment is Fort Carson, Colorado, where a Neptune Micro Floc filter is utilized.

Table 12. SIGNIFICANT INDUSTRIAL WASTES CONTAINED IN INFLUENT RAW SEWAGE FOR IRRIGATION REUSE

Pollutant source	Number of treatment plants affected*	Percent of treatment plants producing water for irrigation
Industrial Process		
Paper & Textile Mfg.	1	1
Laundry	6	5
Unspecified	4	3
Chemicals		
Plating	10	8
Photographic	1	1
Unspecified	3	3
Food Process		
Meat packing	10	8
Fruit and vegetable	5	4
Dairy	7	6
Unspecified	6	5
None	71	56

*Certain plants are affected by more than one waste type.

Table 13. MUNICIPAL TREATMENT PROVIDED FOR IRRIGATION REUSE ON SPECIFIC CROPS

Crop	Number of treatment plants*	Treatment level (% of plants)		
		Primary	Secondary	Tertiary
Grain	17	23	77	0
Corn	11	36	64	0
Vegetables	6	14	86	0
Fruit	12	18	82	0
Cotton	26	29	71	0
Fodder	51	24	73	3
Pasture	34	20	71	9
Turf and Landscape	47	9	70	21

*Certain plants supply water to more than one crop.

(See Appendix A for a detailed discussion). However, in many cases, irrigation is an adjunct to direct reuse demanding high quality water, for recreation (CA-65) or industry employed solely for the irrigation application.

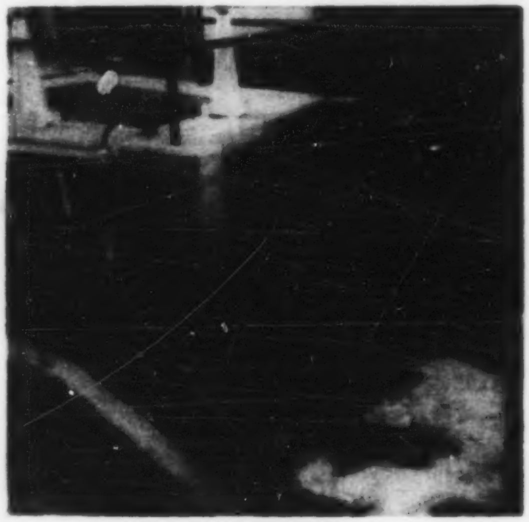

FIGURE 3

RECLAIMED WASTEWATER DIVERTED FOR IRRIGATION OF CROPS AND GOLF COURSES LAS VEGAS, NEV.

The crops classified in Table 13 are listed again in Table 14 to summarize the quality of effluent currently employed in agricultural reuse. Table 14 must be viewed only in the most general terms, however, since parameters from all levels of treatment are averaged together; furthermore, the diverse tolerances of specific crops within one category (e.g., vegetables) preclude a judgment of effluent adequacy by an averaged value from several plants. It is recommended that treatment adequacy be analyzed on an individual plant basis relative to the crop types anticipated.

Many of the current users of renovated wastewater consider their supplies to be substandard to fresh water sources. Municipal wastewater, however, has a substantial value in fertilizer elements required by all crops. Table 15 compiles the results of several researchers as summarized by Williams, et. al.(10) These authorities estimate than an

Table 14. QUALITY OF EFFLUENT APPLIED TO CROPS

CROP	NO. PLANTS IRRIGATING*	BOD (mg/l)			SS (mg/l)			TDS (mg/l)		
		LOW	HIGH	AVG	LOW	HIGH	AVG	LOW	HIGH	AVG
Grain	17	10	1100	180	10	173	71	324	1400	837
Corn	11	10	370	76	10	135	69	8	1114	601
Vegetables	6	6	1100	193	6	127	31	5	1114	700
Fruit	12	10	160	32	9	135	58	14	1400	798
Cotton	26	15	370	84	12	259	94	324	2250	854
Fodder	51	1	370	54	0	259	66	8	1450	641
Pasture	34	7	370	50	2	118	40	6	2250	839
Turf & Landscape	47	1	80	19	0	200	26	43	2000	658

* Certain plants supply water to more than one crop.

Table 14 (Continued)

CROP	NO. PLANTS IRRIGATING*	Na (mg/l)			Cl (mg/l)			pH		
		LOW	HIGH	AVG	LOW	HIGH	AVG	LOW	HIGH	AVG
Grain	17	87	300	204	10	300	130	6.8	9.9	7.7
Corn	11	56	220	137	49	200	105	6.8	8.7	7.6
Vegetables	6	0	321	163	160	283	212	6.5	9.9	7.5
Fruit	12	100	300	176	115	300	176	7.0	8.4	7.6
Cotton	26	87	450	211	0	460	163	6.7	8.7	7.4
Fodder	51	5	300	167	0	380	154	6.7	8.7	7.2
Pasture	34	10	450	193	2	460	149	6.5	9.2	7.6
Turf and Landscape	47	5	400	140	0	400	109	6.7	9.5	7.4

*Certain plants supply water to more than one crop.

acre-ft. of treated municipal wastewater contains approximately 17 to 18 dollars of commercial fertilizer value; furthermore, some studies indicate, optimistically, that almost all fertilization requirements can be met by wastewater alone.(10)

Table 15. TYPICAL FERTILIZER CONTENT OF SECONDARY TREATED MUNICIPAL WASTEWATER(10)

Researcher	Nitrogen	Phosphorus	Potassium
Hershkovitz	5.5-6.6 lbs/cap./yr	1.7-2.2 lbs/cap./yr.	2.9-3.5 lbs/cap./yr.
Fair, Geyer, and Okum	6-7 lbs/cap./yr	1.2 lbs/cap./yr.	2 lbs/cap./yr.
Day and Tucker	65 lbs/acre-ft.	50 lbs/acre-ft.	32 lbs/acre-ft.

By extracting the nutrients listed in Table 15, the crops act as a further treatment method to protect surface and groundwater resources. The efficiency of various crops in achieving nutrient removals is listed in Table 16.

The municipal facilities supplying effluent for irrigation generally do not utilize sophisticated instrumentation to monitor the effluent quality. Rural plants with funds available rely heavily on periodic laboratory testing by state health departments and related agencies.

It is interesting to note that 60 percent of the plants surveyed reported no end use quality criteria (Column F7, Appendix B) for irrigation reuse. It is unreasonable to accept almost two-thirds of the operations as having no criteria requirements whatsoever, and presumably most respondents were basing their answer on rejection by the irrigator, not health requirements. One-half the respondents state that their effluents are of acceptable quality 100 percent of the time.

Slightly over half of the reclaimed irrigation water suppliers reported no alternate means of disposal; forty-four percent, however, indicate that their reuse was not total. Factors in their inability to totally reuse the effluent include the following:

- Insufficient storage capacity to coordinate effluent availability with irrigation needs.

Table 16. POUNDS OF NUTRIENTS REMOVED PER ACRE IN HARVESTED CROPS AT VARIOUS LEVELS OF EFFLUENT APPLICATION IN 1963(5)

	RED CLOVER (INCHES)		ALFALFA (INCHES)		CORN* (INCHES)		WHEAT* (INCHES)	
NUTRIENT	1	2	1	2	1	2	1	2
N	216.8	210.7	143.2	191.7	88.3	90.2	63.8	82.7
P	26.0	24.4	23.0	32.0	19.9	23.7	16.1	20.4
K	264.1	243.5	167.9	234.0	16.8	24.8	11.7	11.9
Ca	127.0	119.2	50.0	45.3	0.26	0.27	1.3	1.8
Mg	22.3	21.7	11.4	14.5	5.6	6.9	4.0	5.3

*Grain only

- Uneconomically long distance between plant and additional possible users.
- Insufficient land availability.
- Lack of interest by effluent producer and potential reusers.

Not surprisingly, seasonal conditions dictate effluent utilization. The typical procedure in such cases is to discharge the effluent to a water course during the non-growing season. Conversely, in some situations, not enough effluent can be supplied during the irrigation season to satisfy the demand.

To assist in remedying this fluctuation, many plants have storage facilities available as illustrated in Figure 4.

Effluent transport distances to potential reuse sites is an important economic factor. With one or two exceptions, transport facilities are defined as an engineered pipeline or channel; not an existing river bed into which the effluent is discharged and withdrawn by downstream irrigators. Figure 5 displays the ranges of irrigation water transport distances reported by current agricultural reusers. The figure illustrates that 20 percent of all irrigation reusers are directly adjacent to the municipal treatment site and less than 6 percent are more than 4 miles away. The data received indicates that the bulk of the reusers lie two miles or less from their supplier.

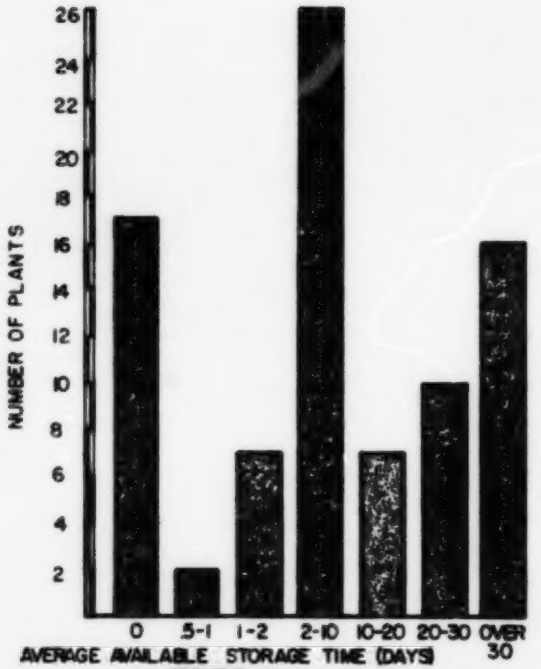

FIGURE 4
STORAGE CAPACITY OF IRRIGATION WATER SUPPLY FACILITIES

IRRIGATION IN ISRAEL

Data obtained from Israel[(12)] shows approximately 40 plants in that country utilizing reclaimed municipal effluent for irrigation with another 34 facilities practicing groundwater recharge. Table 17 on the following page shows the growth of reuse in Israel from 1963 to 1971. Roughly 86 percent of the country's total treated wastewater flow was reused in 1971 (62% for irrigation and 24% for recharge.)

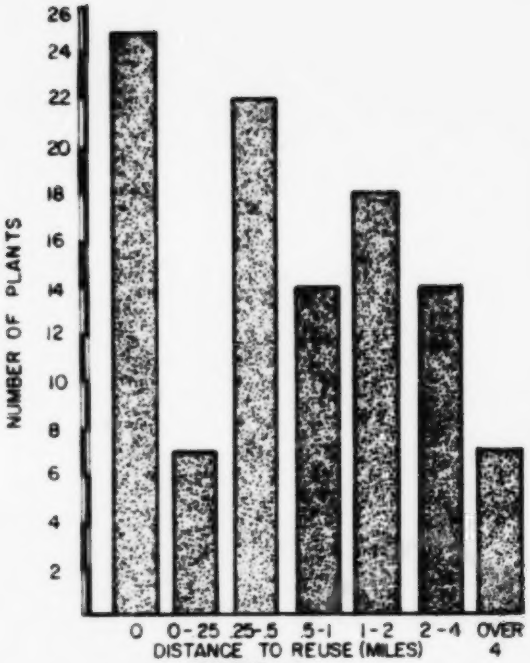

FIGURE 5
TRANSPORT DISTANCE FROM TREATMENT PLANT TO IRRIGATION REUSE

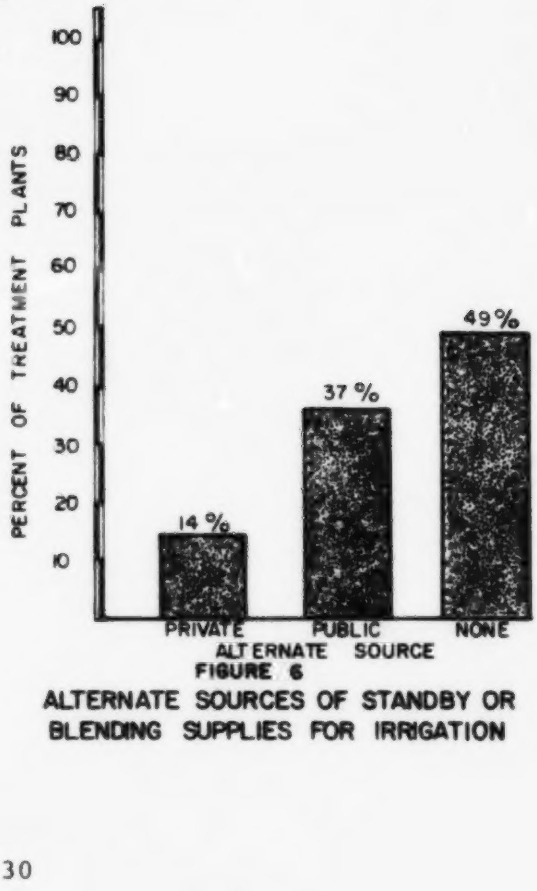

FIGURE 6
ALTERNATE SOURCES OF STANDBY OR BLENDING SUPPLIES FOR IRRIGATION

Figure 6 illustrates that half the irrigation reusers have alternate sources available. Many indicated that their alternate sources are rarely used. Nearly 50 percent of the agricultural reusers are totally dependent upon reuse for successful operations. One of the largest of these is the Buckeye Irrigation District near Phoenix. The irrigational reuse program at Phoenix is described in Appendix A.

Table 17. VOLUMES OF MUNICIPAL REUSE IN ISRAEL (cu. m./day)

	1963 Total	1967 Total	1971 Total
Volume treated	88,440	119,080	155,300
Volume reused	48,470	79,670	133,535
Percent reused	55	67	86

The predominant type of treatment in Israel involves anaerobic and aerobic lagoons. In a few instances these basic systems are enhanced by the addition of Imhoff tanks, sedimentation tanks, and trickling filters.

Table 18 below summarizes Israeli reuse of municipal wastewaters by crop. As can be seen, field crops take the majority of the reclaimed water. However, a significantly high percentage of the reclaimed irrigation water (21%) is used on citrus crops.

Table 18. REUSE OF MUNICIPAL WASTEWATERS, BY CROP IN ISRAEL

Crop	Area Irrigated ha	Area Irrigated %	Quantity of Wastewater Reused cu.m/day	Quantity of Wastewater Reused %
Field crops	1,533.0	61.5	45,680	47.7
Orchards and vineyards	140.0	5.6	4,900	5.2
Citrus	431.5	17.2	19,500	20.6
Other crops	152.0	6.1	5,150	5.5
Pastures	133.0	5.3	10,075	10.0
Fodder crops	107.0	4.3	9,130	9.7
Fish ponds	--	--	1,250	1.3
Total	2,492.5	100.0	95,685	100.0

ANALYSIS OF CURRENT IRRIGATION REUSE ECONOMICS

In a report involving data from many plants, there is the danger of overuse of the data obtained to arrive at broad conclusions which are meaningless for a specific reuse application. This is true particularly of the economics of sewage treatment and reuse which are subject to many factors completely outside of the scope of this study. The reader is urged, therefore, to make a detailed investigation, before applying economic data presented herein to another location where conditions are only superficially similar.

Table 19 presents 1971 treatment costs reported by municipal plants furnishing effluent for irrigation reuse in the United States. The cost per million gallons treated is shown both inclusive and exclusive of capital amortization. The cost exclusive of capital amortization simply represents all annual costs for labor, materials, energy, supplies, and miscellaneous items divided by mg of effluent produced annually. The cost including amortization was developed as shown in Appendix E and is based upon 5.5% interest, 25 year life, and updating of all original construction costs to January 1972.

Figures 8 and 9, depict the information from Table 19 plotted as best-fit curves for functions of average daily plant effluent volumes. It should be remembered that the curves in Figures 8 and 9 represent averages for all degrees of treatment from primary to tertiary.

Figure 7 shows the difference between current costs and revenues for irrigation reuse. Current costs are the total for all producers of reclaimed water for irrigation - not just those who sell their effluent. Only 25 producers of irrigation water sell their renovated product. Most municipalities look upon the irrigation operations as primarily a means of disposal, and are not prone to demanding payment for effluent which they would otherwise waste. In some cases (e.g., CA-4) the irrigation operation allows the municipality to provide only primary treatment, whereas if discharge were made to surface waters a high degree of secondary treatment would be required. The discrepancy between costs and revenues shown in Figure 7 reveals, however, that as a whole municipalities are apparently not demanding sufficient revenue for reclaimed wastewater they supply for irrigation. In

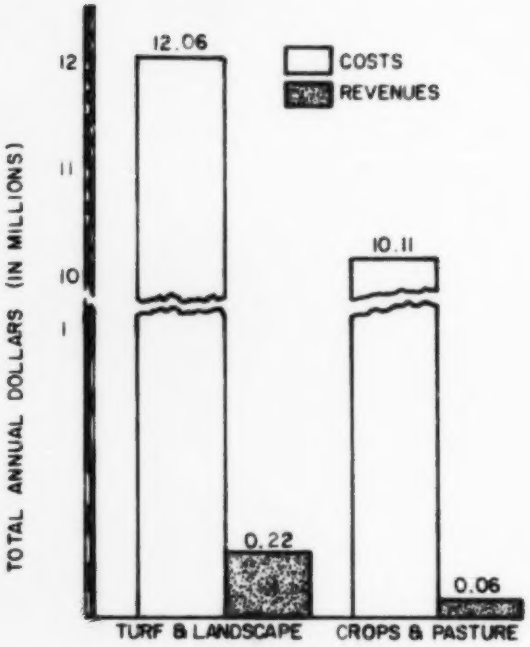

FIGURE 7
MUNICIPAL TREATMENT COSTS AND REVENUES FOR IRRIGATION USES

Table 19. TREATMENT COSTS FOR IRRIGATION REUSE*

Plant code	Trt. cost ($/MG) incl. cap. amort.	Trt. cost ($/MG) excl. cap. amort.	Plant code	Trt. cost ($/MG) incl. cap. amort.	Trt. cost ($/MG) excl. cap. amort.
AZ-2	-	-	CA-30	285	190
AZ-3	145	54	CA-31	262	123
AZ-4	57	22	CA-32	503	259
AZ-5	-	-	CA-33	-	92
AZ-6	2,580	604	CA-34	330	123
AZ-7	-	-	CA-35	441	208
AZ-8	244	76	CA-36	1,411	176
AZ-9	117	60	CA-37	292	93
AZ-11	-	-	CA-38	884	545
AZ-12	72	32	CA-39	130	44
AZ-13	-	4	CA-40	298	83
AZ-14	34	18	CA-41	141	50
AZ-15	698	215	CA-44	251	104
AZ-16	-	-	CA-45	251	104
AZ-17	-	62	CA-46	472	77
			CA-47	36	14
CA-1	-	151	CA-48	253	127
CA-2	485	254	CA-49	359	23
CA-3	-	-	CA-50	523	353
CA-4	113	58	CA-51	-	3,209
CA-5	92	38	CA-52	-	-
CA-6	144	80	CA-53	476	229
CA-7	245	185	CA-54	1,416	472
CA-9	348	244	CA-55	355	100
CA-11	519	322	CA-56	-	-
CA-12	-	272	CA-57	394	-
CA-13	-	144	CA-59	483	348
CA-14	-	-	CA-60	311	207
CA-15	-	56	CA-61	405	290
CA-16	143	143	CA-62	1,399	448
CA-17	902	49	CA-63	520	268
CA-18	171	30	CA-64	253	93
CA-19	88	41	CA-65	1,747	1,086
CA-20	61	26	CA-66	223	41
CA-21	57	18	CA-67	1,258	794
CA-22	289	166	CA-68	-	142
CA-23	79	42	CA-69	174	30
CA-24	79	42	CA-70	2,703	1,005
CA-25	936	395	CA-71	47	22
CA-26	276	128	CA-72	580	112
CA-27	-	12	CA-73	6,363	1,411
CA-28	206	123	CA-74	6,566	5,606
CA-29	408	127	CA-75	1,231	476

Table 19. (Continued)

Plant code	Trt. cost ($/MG) incl. cap. amort.	Trt. cost ($/MG) excl. cap. amort.
CA-76	-	-
CA-77	-	25
CA-78	-	36
CO-1	322	152
CO-2	28	15
CO-3	498	125
CO-5	-	-
CO-6	363	137
FL-1	522	161
FL-2	174	163
ID-1	310	193
MI-1	-	-
MO-1	-	-
MO-2	1,381	429
NE-1	128	29
NV-1	29	4
NV-2	66	44
NV-3	288	193
NV-4	352	193
NM-1	47	-
NM-2	-	-
NM-3	-	-
NM-4	-	-
NM-5	-	-
NM-6	-	-
NM-7	506	95
NM-8	190	68
NM-9	429	119
NM-10	-	-
ND-1	115	18
OK-2	2,806	415
OR-1	1,273	823
TX-1	-	-
TX-2	219	73
TX-5	144	42
TX-6	114	54
TX-7	-	-
TX-8	134	80
TX-10	495	338
TX-11	82	22
TX-12	-	-
UT-1	720	83
WA-1	93	39
WA-2	109	59

*See Appendix E for calculation procedure.

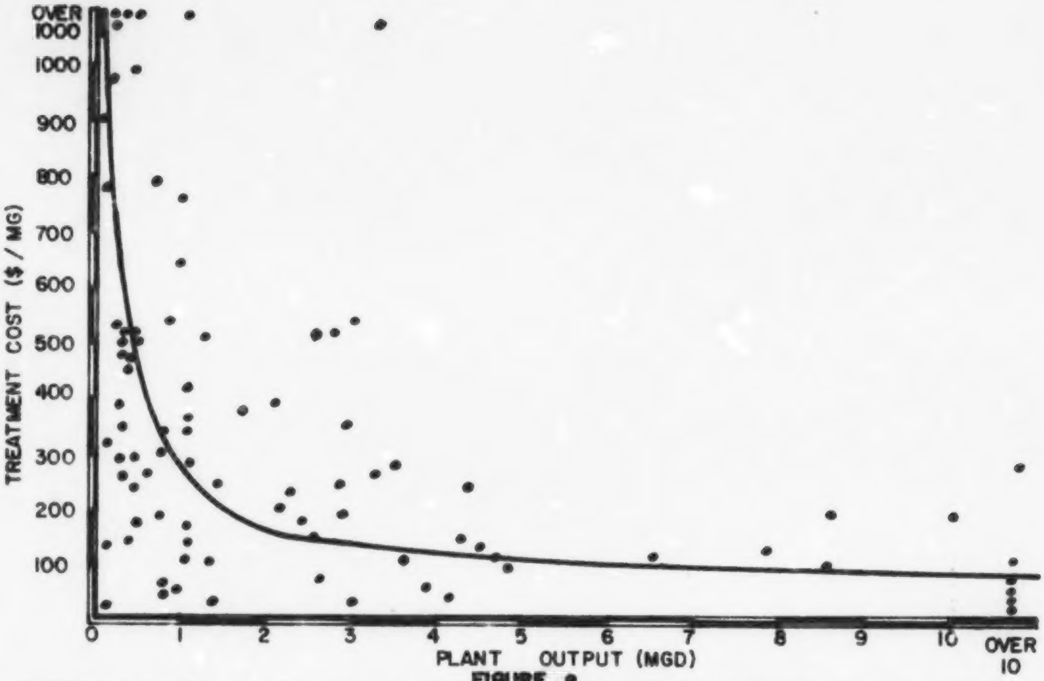

FIGURE 8
EFFECT OF EFFLUENT VOLUME ON TREATMENT COSTS FOR IRRIGATION REUSE (INCLUDING CAPITAL AMORTIZATION)

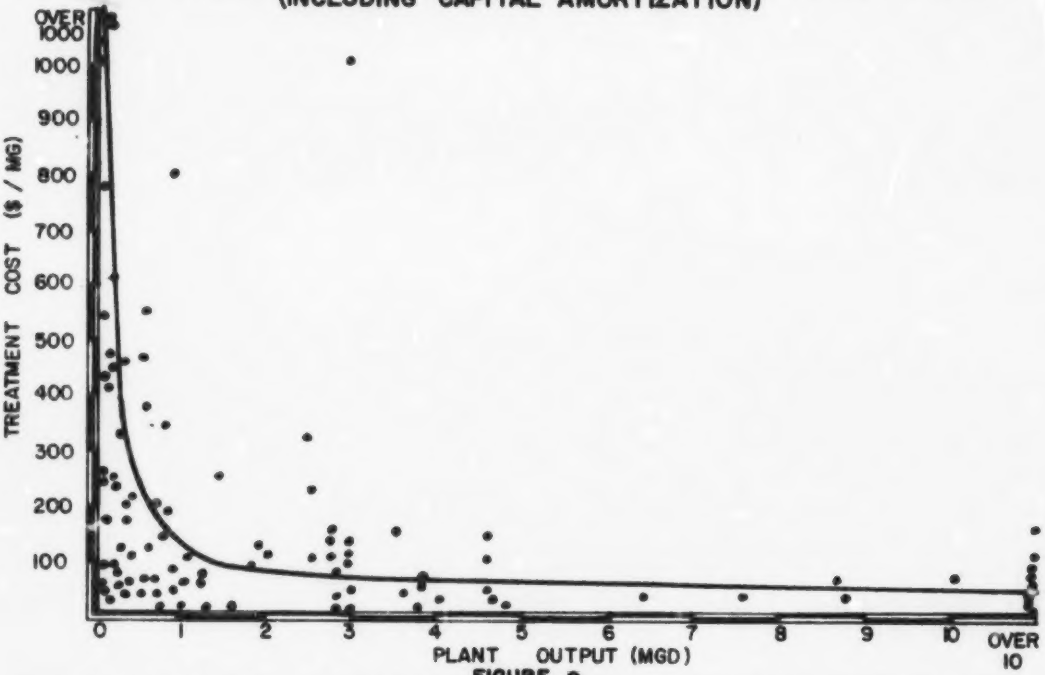

FIGURE 9
EFFECT OF EFFLUENT VOLUME ON TREATMENT COSTS FOR IRRIGATION REUSE (EXCLUDING CAPITAL AMORTIZATION)

all cases, however, any revenue is more than they would obtain through disposal.

Table 20 shows the range of effluent charges by those 25 suppliers who currently charge for their effluent. The majority of these charge less than $150/MG. Table 20 does not differentiate between the level of treatment provided; thus, to determine whether user charges are equitable, facilities should be investigated on an individual basis.

Table 20. RANGES OF EFFLUENT CHARGES FOR IRRIGATION REUSE

Range of Charges for Effluent ($/MG)	No. of Suppliers
1 - 150	17
151 - 300	5
301 - 900	0
901 - 1,000	3

Figure 10 on the following page shows how the level of treatment affects municipal charges for irrigation water. The results, as expected, indicate better treatment allows higher charges for the effluent. The high average price for tertiary treated water is due mainly to the Grand Canyon, Arizona (AZ-6) facility which charges $1,000/MG. When weighted average is used, the tertiary price shown in Figure 10 decreases from $337 to $76/MG because the daily volume of the Grand Canyon facility is only 0.03 mgd.

Several suppliers charge on either an indirect or flat-rate basis. The typical indirect basis (e.g., CA-2, CA-3, CA-18) gives the grower all water and land in exchange for a percentage of his farm income. This percentage ranges from 20 to 25 percent.

Flat-rate charges for effluent fall into two categories: token fees and compensatory fees. Token fees (e.g., CA-44, CA-45, CA-47) are imposed to fulfill legal obligations and protect water rights. The three facilities cited here charge $1.00 per year to users. Compensatory fees (e.g., NM-2, NM-3, NM-4, NM-5, NM-9) are designed to partially defray the costs of treatment. The responders to this study indicated charges in the range of $200 to $1,000 annually. In several cases the price is set by bids received from several interested potential users.

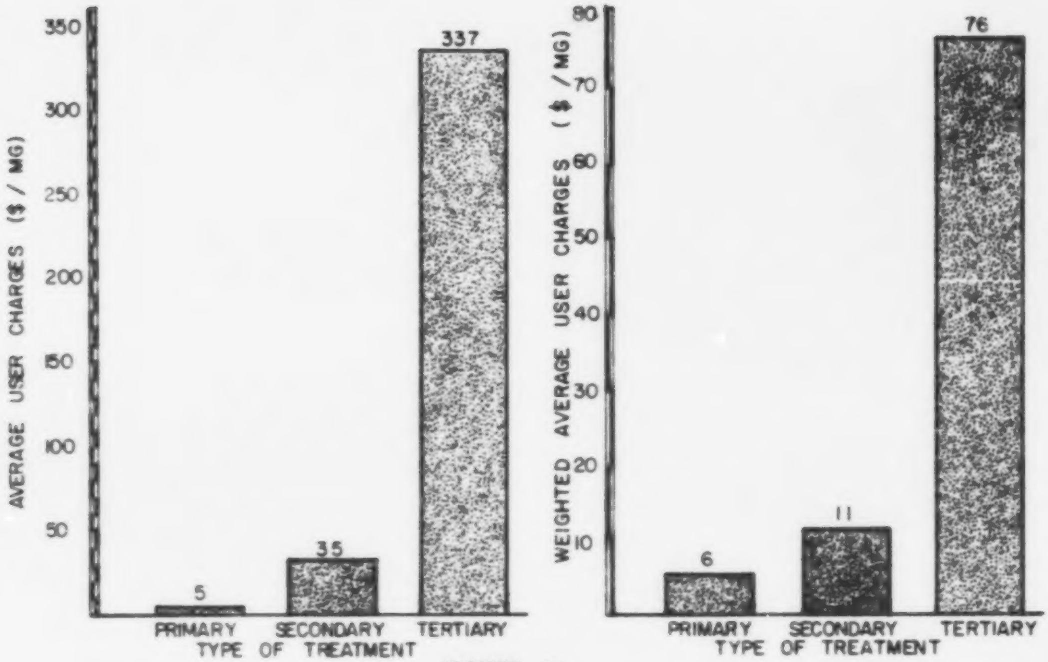

FIGURE 10

USER CHARGES FOR IRRIGATION REUSE RELATIVE TO LEVELS OF TREATMENT

The results of the study revealed little economic correlation among the relationships listed below:

- TDS concentration vs. total effluent sales, shown in Figure 11.
- Effluent volume vs. average user charge, shown in Figure 12.
- TDS concentration vs. average user charge, shown in Figure 13.
- BOD concentration vs. average user charge, shown in Figure 14.

It appears that charges for effluent are primarily influenced by factors other than effluent quality. Among these factors are fresh water cost and availability in the area, prior water rights in the area, and the municipality's failure to recognize its effluent as a valuable commodity rather than something to be discarded.

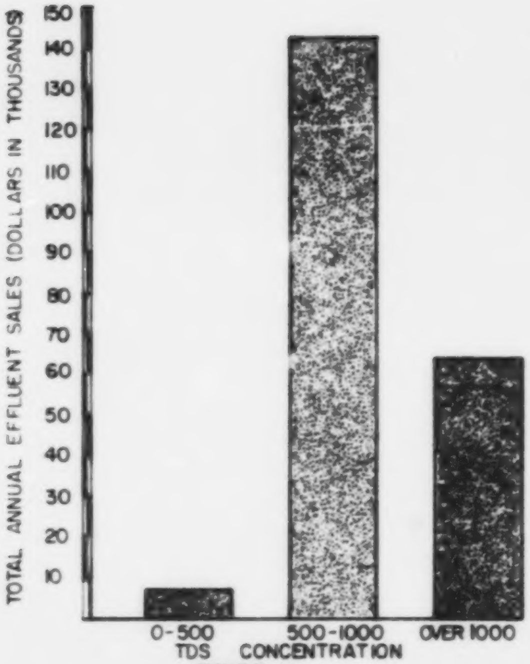

FIGURE 11

SALES FOR IRRIGATION REUSE AS A FUNCTION OF TDS CONCENTRATIONS

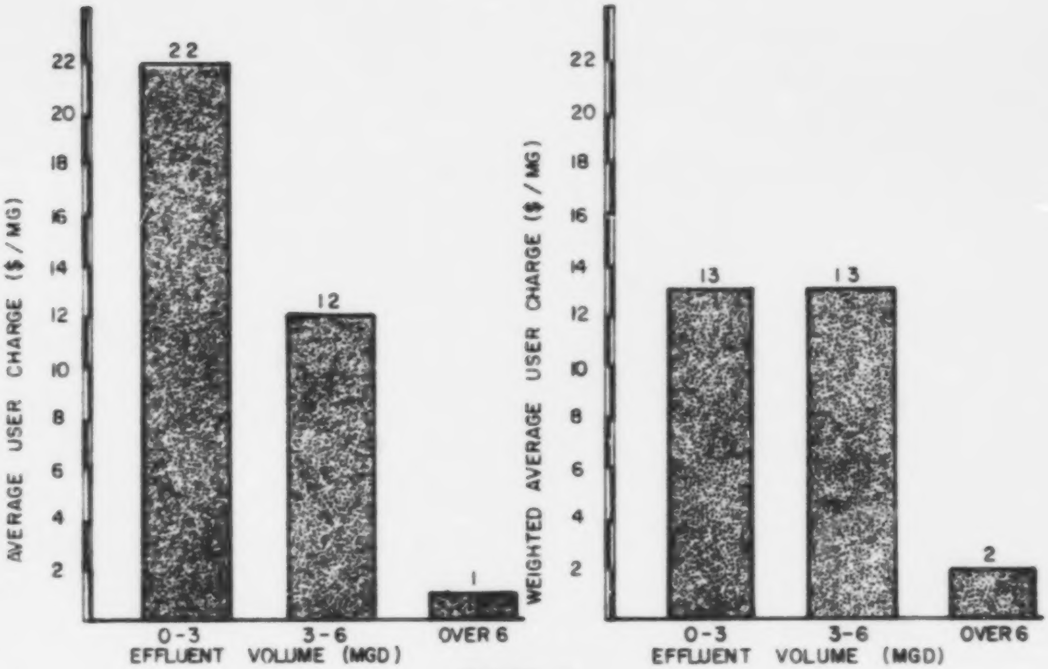

FIGURE 12

EFFECT OF PLANT EFFLUENT VOLUME ON IRRIGATION USER CHARGES

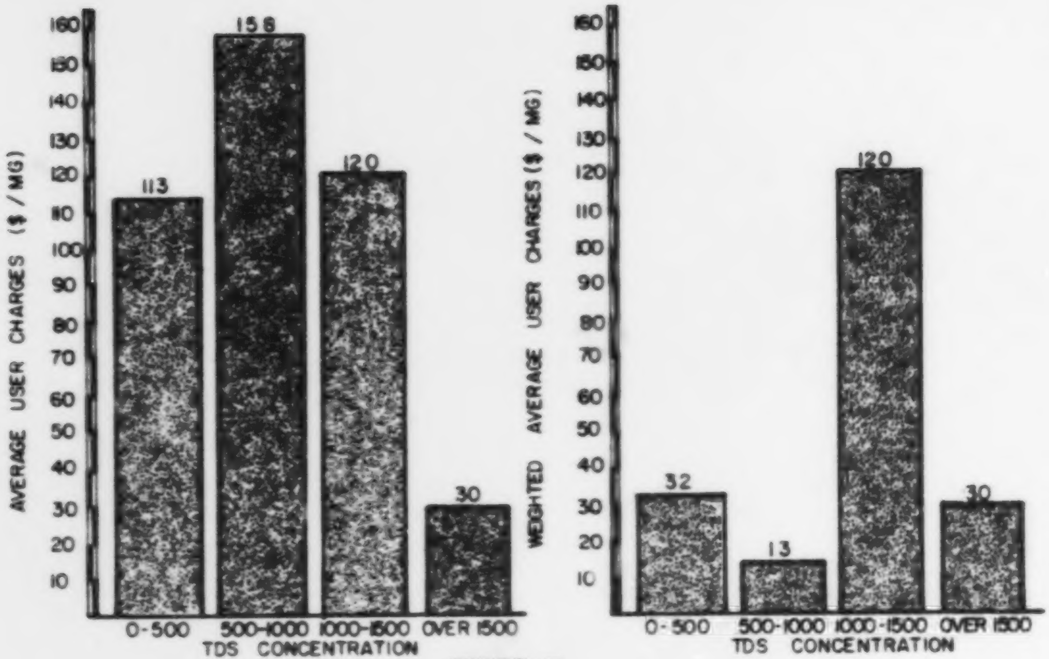

FIGURE 13
USER CHARGES FOR IRRIGATION REUSE RELATIVE TO TDS CONCENTRATIONS

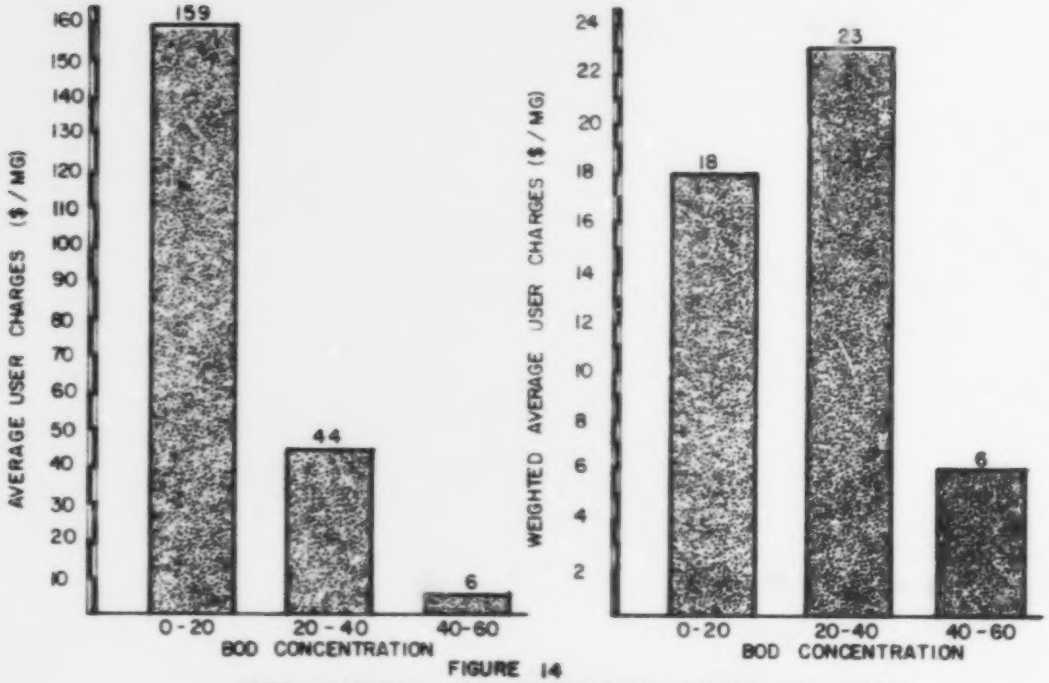

FIGURE 14
USER CHARGES FOR IRRIGATION REUSE RELATIVE TO BOD CONCENTRATIONS

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SECTION III

INDUSTRIAL REUSE

INTRODUCTION

Responses to this survey indicated that reuse of municipal wastewater effluents by industry amounted to 53.5 billion gallons in 1971, or 40 percent of the total United States reuse volume. The bulk of the industrial reuse volume is due to one user; the Bethlehem Steel Plant in Baltimore, Maryland, which utilizes 44 billion gallons annually.

Figure 15 depicts the growth of industrial reuse since 1930, as determined by the year in which the plants surveyed began reuse. Only 15 industrial plants are presently reusing municipal wastewater in the United States. These 15 facilities include three city-owned power plants, so private industry is represented by only 12 plants in the entire nation. Obviously, numerous potential reuse opportunities remain unrecognized.

Nine of the industrial reuse facilities were visited during the project and detailed descriptions of their operations are presented in individual case studies contained in Appendix A.

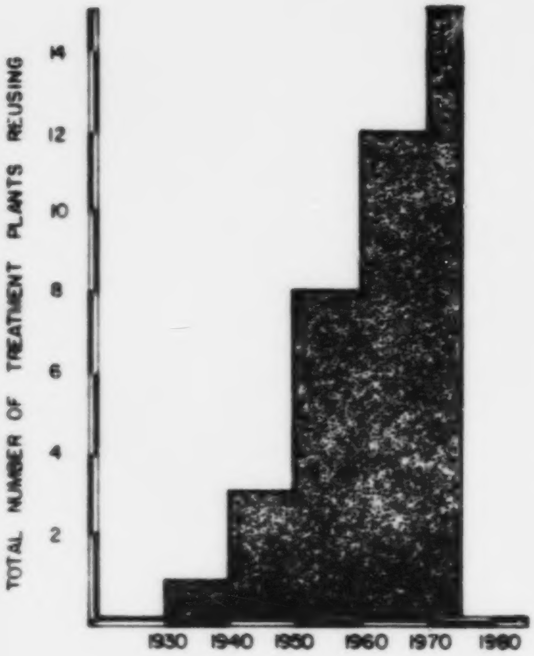

FIGURE 15
GROWTH OF INDUSTRIAL REUSE

This chapter is divided into three sections as follows:

- Required water quality, which is derived from existing literature sources and this study.
- Analysis of current reuse by industry which is largely derived from the data developed during this study.
- Analysis of current economics, which is largely derived from data developed during this study.

REQUIRED QUALITY CRITERIA

General

Water quality requirements vary widely between industries, between different plants in the same industry, and between various processes within a single plant. It is impossible, therefore, to present quality criteria for all industrial operations. References 1, 2, 3, and 4 at the end of this chapter contain substantial general information pertinent to water quality requirements by most of the major water using industries. The bulk of industrial water is used for cooling, boiler feed, washing, transport of materials, and as an ingredient in the product itself. Of these uses, cooling is predominant in the reuse of municipal wastewater, accounting for approximately 145 mgd out of the total 147 mgd reported industry reuse.

Cooling Water

Cooling water systems may be broadly classified as either "once through" (e.g. MD-1) or recirculating (e.g. CA-8, NV-2, NV-3).

Once through cooling systems, as the name implies, use intake water for only one cooling cycle and then discharge it. The intake water need not be of high quality. Sea water and polluted river waters are commonly used with minimal treatment, such as coarse screening and periodic shock chlorination. The Bethlehem Steel Company cooling system which uses Baltimore, Maryland, municipal effluent is a once through system. The effluent successfully used by Bethlehem for over 20 years is relatively poor quality secondary effluent. A detailed description of their operation is given in Appendix A.

Recirculating cooling systems, on the other hand, continually recirculate the same cooling water for many cycles by utilizing cooling towers or spray ponds to recool the water after each heat exchange cycle. To prevent unacceptable build-up of contaminants, a portion of the recirculating water is continuously wasted. This waste discharge is called blowdown, and is representative of the quality of the recirculating water. To replace the volume lost in blowdown the recirculating cooling system requires makeup water. Contaminants present in makeup water are concentrated many times during the cooling cycles, and organics and nutrients in the makeup water furnish food for organisms. Thus, it is important for the makeup water to be of high quality. Sewage effluent treated to a high degree is successfully used for cooling makeup water at nine locations as described later in this chapter.

The basic requirements for cooling waters are that they:

- Do not form scale on heat exchange surfaces.
- Are not corrosive to metal in the cooling system.
- Do not supply nutrients promoting the growth of slime-forming organisms.
- Do not foam excessively.
- Do not deteriorate wood in cooling towers.

The literature provided several lists of water quality for cooling water supplies which are summarized in Table 21. As indicated later in this chapter, sewage effluent is being successfully used with higher TDS than recommended, however all successful users reduce their organics and nutrients to very low levels.

Boiler Feed Water

Quality requirements for boiler feed makeup water are dependent upon the pressure at which the boiler is operated. The higher the pressure, the higher the quality of water required. Very high pressure boilers require makeup water of distilled quality or better. Table 22 shows quality tolerances recommended by several authorities. As described in the following section of this chapter, three industrial users of treated sewage effluent for boiler feed water makeup were reported, with a total volume requirement of approximately 1 mgd. All users reduce the hardness of the boiler feed makeup water to close to zero. Low pressure boilers, e.g. 200 psig, report use of effluents with TDS concentrations as high as 1,000 mg/l.

Table 21. COOLING WATER QUALITY REQUIREMENTS FOR MAKEUP WATER TO RECIRCULATING SYSTEMS

Parameter	Reference (2)	Reference (3)	SCS comment based on this study
Cl	500		up to 460 successfully used
TDS	500	--	up to 1,650 successfully used
Hardness ($CaCO_3$)	130	50	--
Alkalinity ($CaCO_3$)	20	--	--
pH	aar	6.9-9.0	preferably 6.8-7.2
COD	75	--	preferably below 10
TSS	100	25	preferably below 10
Turbidity	--	50	preferably below 10
BOD	--	25	preferably below 5
MBAS	--	2	2 is good
NH_3	--	4	preferably below 1
PO_4	--	1	<1 is good
SiO_2	50	--	--
Al	0.1	--	--
Fe	0.5	0.5	--
Mn	0.5	--	--
Ca	50	--	--
Mg	aar	0.5	--
HCO_3	24	--	--
SO_4	200	--	--

Note: aar = accepted as received

High pressure boilers, e.g. 650-1,500 psig, however, in both reported uses demineralize the effluents to TDS concentrations of under 2 mg/l.

Silica and aluminum are very undesirable because they form a hard scale on heat exchange surfaces. Pottasium and sodium in higher concentrations can cause excessive foaming of the boiler water.

ANALYSIS OF CURRENT INDUSTRIAL REUSE

Only 15 industrial plants, as listed in Table 23 and located in Figure 16 were reusing municipal wastewater in the United States during 1972.

Table 22. QUALITY TOLERANCES FOR CONSTITUENTS OF INDUSTRIAL BOILER FEEDWATER

Quality Parameter	American Boiler Manufacturers Association, (ABMA)[1*]							New England Water Works Association (NEWWA)[2]				Federal Water Pollution Control Administration (now EPA)[3]		
	Pressure ranges, psig							Pressure ranges, psig				Pressure ranges, psig		
	0-300	301-450	451-600	601-750	751-900	901-1000	1001-1500	0-150	150-250	250-400	over 400	0-150	150-700	700-1500
TDS, ppm	3500	3000	2500	2000	1500	1250	1000	3000-500**	2500-500	1500-100	50	700	500	200
Suspended solids, ppm	300	250	150	100	60	40	20	N.S.	N.S.	N.S.	N.S.	10	5	0.5
Silica, ppm	N.S.[+]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	40	20	5	0.0	30	10	0.7
Hardness as $CaCO_3$, ppm	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	80	40	10	2	20	0.0	0.0
Alkalinity, ppm	700	600	500	400	300	250	200	N.S.	N.S.			140	100	40
pH, units	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	8.0	8.4	9.0	9.6	8.0-10.0	8.2-10.0	8.2-9.0
Dissolved oxygen, ppm	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1.5	0.10	0.0	0.0	2.5	0.007	0.007
Iron, ppm	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1.0	0.30	0.05
Manganese, ppm	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.3	0.10	0.01
Aluminum, ppm	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	5	0.5	0.05	0.01	5	0.10	0.01
Bicarbonate, ppm	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	50	5	5	0.0	170	120	0.01
Chloride, ppm ppm	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	NP[‡]	NP	NP
Sulfate, ppm	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	NP	NP	NP

*Sources: 1. from reference (2)
2. from reference (3)
3. from reference (4)

** Varies with boiler design
+ N.S. - not specified
‡ NP - no problem at levels normally encountered

Table 23. INVENTORY OF INDUSTRIAL REUSE OPERATIONS IN THE UNITED STATES

Location	Producer	User	Purpose
Bagdad, Arizona	Bagdad Copper Corporation	Same	Process
Morenci, Arizona	Phelps Dodge Corporation	Same	Process
Burbank, California	City of Burbank	City Power Generating Station	Cooling
Colorado Springs, Colorado	City of Colorado Springs	City Electric Division Martin Drake Plant	Cooling
Baltimore, Maryland	City of Baltimore	Bethlehem Steel Corporation	Cooling and Process
Midland, Michigan	City of Midland	Dow Chemical Company	Cooling
Las Vegas, Nevada	City of Las Vegas	Nevada Power Company	Cooling
Las Vegas, Nevada	Clark County Sanitation District	Nevada Power Company	Cooling
Enid, Oklahoma	City of Enid	Champlin Refinery	Cooling
Amarillo, Texas	City of Amarillo	Southwestern Public Service Company Texaco, Inc.	Cooling
Big Spring, Texas	City of Big Spring	Cosden Oil and Chemical Co.	Boiler feed
Denton, Texas	Dity of Denton	Municipal Steam Electric Plant	Cooling
Lubbock, Texas	City of Lubbock	Southwestern Public Service Company	Boiler feed and cooling
Odessa, Texas	City of Odessa	El Paso Products Company	Boiler feed and cooling

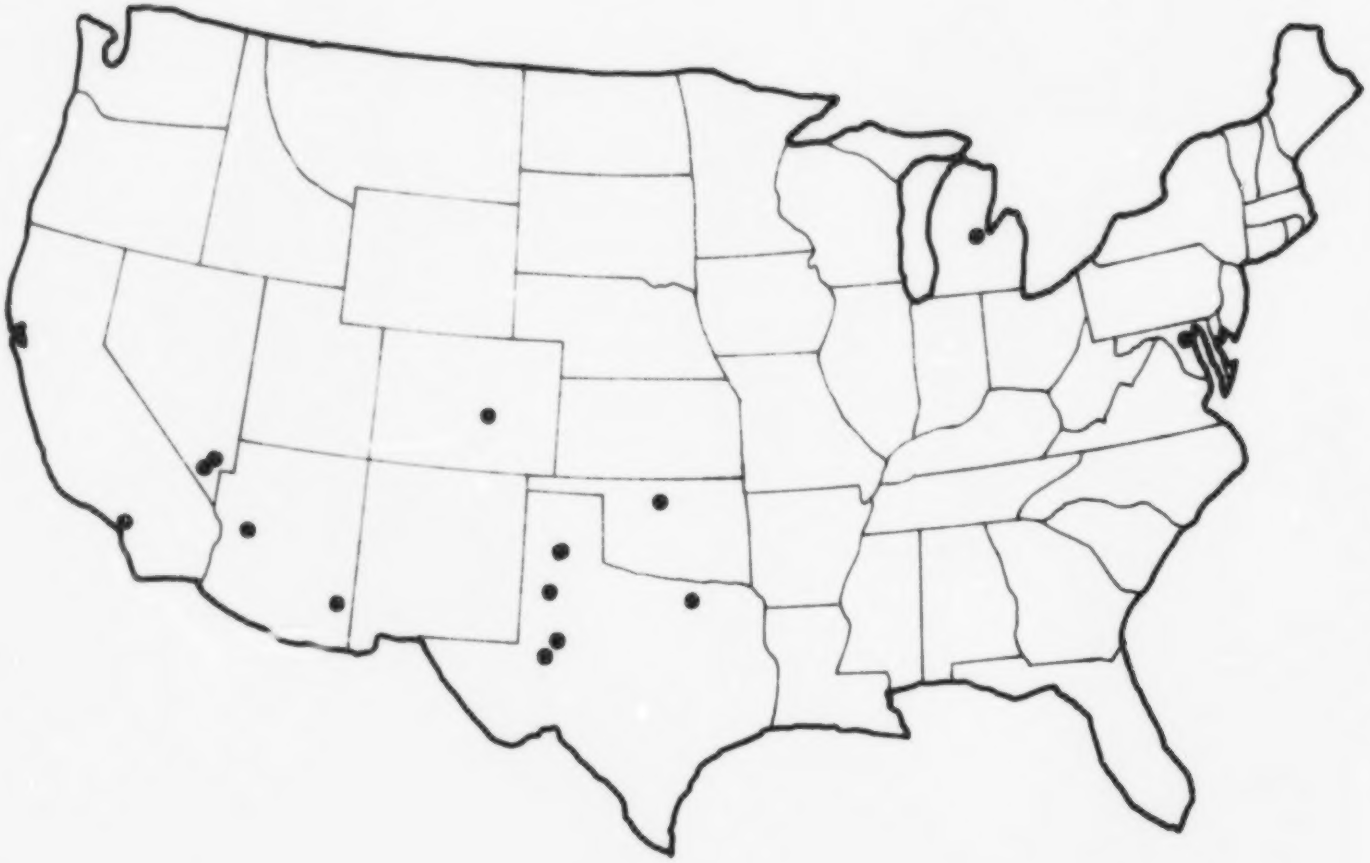

FIGURE 16
GEOGRAPHICAL LOCATIONS OF INDUSTRIAL REUSERS
OF MUNICIPAL WASTE WATER

Industrial reuse operations in foreign countries are listed in Table 24. With few exceptions cost and technical information was not obtained from foreign industrial reusers, and Table 24 is derived primarily from the technical literature.

Detailed technical information pertinent to each American industrial use is summarized in Table 25. The major industry classifications using municipal wastewater, and the approximate percentage of the total volume used by each is shown in Table 26. Basic metals manufacturing at 74 percent of the total volume, followed by power generation at 20 percent, petro-chemical at 5 percent, and ore processing at 1 percent represent all the industries presently reusing municipal wastewater. Again, relative usage volumes are distorted by the large volume used by the Bethlehem Steel Company in Baltimore, Maryland for their once through cooling operation.

In terms of industrial usage, Table 27 shows that the major volume of reclaimed sewage is used for cooling water, with minor quantities used for boiler feed makeup water and manufacturing processes.

Cooling Water

Twelve of the fifteen industrial reusers report cooling water as the primary use for the reclaimed municipal sewage. Cooling water technology is complex, and the use of reclaimed sewage presents special problems of treatment and control to responsible operating personnel. The differences between treated sewage effluent and fresh water must be recognized and planned for, or serious problems may occur in the heat exchange and cooling system. For example, the city of Denton, Texas began using its municipal sewage effluent as cooling water makeup to its municipal power generation plant in early 1972 and rapidly experienced massive condenser tube fouling and other problems. The effluent produced by the Denton Sewage Treatment plant is of only average quality, as seen in Table 28, with wide fluctuations in quality because the plant is on the verge of being overloaded. The Denton power generating station has no treatment facilities to remove suspended solids, organics or nutrients from the reclaimed sewage. Problems at Denton were inevitable, and the experience of other users indicate that the Denton difficulties can only be resolved by great improvement in the Denton sewage effluent or installation of treatment facilities at the power plant to remove suspended solids and organics. Appendix A presents a case study discussion of the reclamation and reuse program at Denton.

Table 24. INVENTORY OF INDUSTRIAL REUSE OPERATIONS IN FOREIGN COUNTRIES

LOCATION	PRODUCER	USER	PURPOSE
Belmont, West. Australia	City of Belmont	Western Mining Corp., Ltd.	Process
Perth, West. Australia	City of Perth	Dampier Mining Co., Ltd.	Process
		Hamersley Iron Pty., Ltd.	Process
		Mt. Newman Mining Co.	Process
Bristol, England	City of Bristol	Bristol Corp. and Imperial Smelting Corp., Ltd.	Process
Derby County, England	Derby County Borough	Refuse Incinerator	Cooling
Dunstable, England	Borough of Dunstable	Cement Works	Process
Nottingham, England	City of Nottingham	Skins and Offal Processor	Cooling
Nuneaton, England	Borough of Nuneaton	Offal Renderer	Cooling
Oldham County, England	Oldham County Borough	Power Station	Cooling
Scunthorpe, England	Scunthorpe Borough	Steel Manufacturer	Cooling
Sheffield, England	City of Sheffield	Steel Manufacturer	Cooling
Stoke-on-Trent, England	City of Stoke-on-Trent	Steel Manufacturer	Cooling
		Gas Producer	
		Tire Manufacturer	
		Power Station	

Table 24. (Continued)

LOCATION	PRODUCER	USER	PURPOSE
Haifa, Israel	Greater Haifa Regional Sewerage Authority	Oil Refineries, Ltd.	Cooling
Kawasaki, Japan	Iriezaki Sewage Treatment Plant	Shin Toyo Glass Company	Cooling
		Nippon Kokan Mizue Iron Works	Cooling
		Toa Oil Company	Cooling
Nagoya, Japan	Tatsumi Industrial Water Plant	Sumitomo Metal Company	Cooling
Osaka, Japan	Tsumori Sewage Treatment Plant	Yamato Steel Works	Cooling
Tokyo, Japan	Mikawashima Sewage Treatment Plant	Senju Paper Mfg. Com.	Cooling and Process
	Minamisenju Industrial Water Plant	180 plants	Cooling and Process
	Minamisunamachi Industrial Water Plant	150 plants	Cooling and Process
Mexico City, Mexico	City of Mexico City	Federal Commission of Electricity	Cooling
Monterrey, Mexico	City of Monterrey	Celulosa y Derivados, S.A.	Cooling, Boiler Feed, and Process
		Aceros Planos, S.A.	
		Papelera Maldonado	

Table 24. (Continued)

LOCATION	PRODUCER	USER	PURPOSE
Monterrey, Mexico (Cont.)		Agua Industrial de Monterrey S. de U. Federal Commission of Electricity	
Pretoria, South Africa	City of Pretoria	Rooiwal Power Generation Station	Cooling

Table 25. SUMMARY OF INDUSTRIAL OPERATIONS

			PRODUCER INFORMATION												
			INFLUENT			AVERAGE CHARACTERISTICS OF EFFLUENT TO REUSE									
QUESTIONNAIRE RESPONSE NUMBER →		A5	B1a	B2b	B3	C1a	C1c	C2a	C2b	C2c	C2d	C2e	C2f	C2g	C2h
CASE NUMBER	MUNICIPAL PLANT LOCATION	YEAR REUSE BEGAN	TOTAL AVERAGE VOLUME, MGD	INDUSTRIAL WASTE, %	SIGNIFICANT INDUSTRIAL WASTE TYPES	AVERAGE REUSE VOLUME, MGD	SEASON OF MAXIMUM REUSE	BOD, Mg/l	SS, Mg/l	TDS, Mg/l	Na, Mg/l	CHLORIDES, Mg/l	pH	COLIFORMS, MPN	HEAVY METAL TYPES
A3-130	Bagdad, AZ	1967	0.2	0	none	0.2	non	14	100	100	18	12	6.8	...	none
A3-515	Morenci, AZ	1957	0.6	0	none	0.6	non	...	...	...	...	...	...	...	...
C1-160	Burbank, CA	1967	5.2	25	Aircft. mfg.	2.0	Sum	2	2	500	88	82	7.2	0-20	trace
C2-186	Colorado Springs, CO	1971	21	10	Plating Elect. Mfg.	2.0	Win	8	2	650	50	20	6.9	225	...
M2-130	Baltimore, MD	1942	170	4	...	120	...	46	44	450	75	100	7.0	5×10^6	trace
M4-510	Midland, MI	1968	6	10	none	6.0	Sum	25	25	450	...	250	7.6	1000	none
N2-471	Las Vegas, NV	1958	27	0	none	3.8	Spr Sum	21	18	985	...	...	7.8	...	...
N2-470	Las Vegas, NV Clark County San. Dist.	1962	12.5	0	none	4.3	Spr Sum	19	22	1550	...	130	7.6	...	...
O2-250	Enid, OK	1954	5	20	...	2.0	...	31	32	600	...	...	7.4	...	...
T2-115	Amarillo, TX	1954	10	7	Meat, Laundry, Food	4.5	...	10	15	1400	300	300	7.7	0	none
T2-140	Big Spring, TX	1943	0.5	0	none	0.5	...	35	30	980	...	...	7.0	...	...
T2-202	Denton, TX	1972	6	1	Metals, Meat	1.5	...	35	38	127	...	70	7.2	16,000	Cr,Zn
T2-497	Lubbock, TX	1938	6.5	20	Dairy, Plating	2.8	...	18	20	1650	450	460	7.8	...	...
T2-575	Odessa, TX	1956	6.5	1	Chromates	1.7	Sum	10	13	1300	...	250	7.4	6×10^5	...

LEGEND

QUALITY MONITORING DEVICES

Cl_2	Cl_2 Residual Analyzer
CON	Conductivity Meter
LAB	Laboratory Analysis
pH	pH Analyzer
TURB	Turbidimeter

PURPOSE OF REUSE

DOM	Domestic
FISH	Fish Habitation
IND	Industrial
IRR	Irrigation
GWR	Ground Water Recharge

END USE CRITERIA

BOD	Low BOD Required
B	Low Boron Required
Cl	Low Cl Required
DIS	Disinfection Required
DWQ	Drinking Water Quality
FD	Free of Debris
NH_3	Low NH_3 Required
OR	Odor Removal
pH	pH Adjustment Required
SHD	State Health Department Stds.
SS	Low SS Required
TDS	Low TDS Required
USPHS	U.S. Public Health Stds.

SUPPLEMENTAL SUPPLY

PRS	Private Source
PS	Public Source

Table 25. (Continued)

PRODUCER INFORMATION					USER INFORMATION					MUNICIPAL SEWAGE TREATMENT PLANT DESIGN INFORMATION						
REVENUE (Cost Data in Appendix)		SYSTEM RELIABILITY														
D7	D8	E1	E2	E3	F6	F7	F9	F10	F8	G5	F6 & 7	F8b	F9	F10	QUESTIONNAIRE RESPONSE NUMBER	
UNIT CHARGES FOR EFFLUENT, $/MG	TOTAL 1971 EFFLUENT SALES, $1000	SUBSTANDARD EFFLUENT, %	QUALITY MONITORING DEVICES	INTERRUPTION TOLERATION	PURPOSE OF REUSE	END USE QUAL. CRITERIA	ADDITIONAL TREATMENT	QUALITY SAFEGUARDS	SUPPLEMENTAL SUPPLY	DESIGN CAPACITY, MGD	TREATMENT PROCESSES	EFFLUENT STORAGE CAPACITY, MG	EFFLUENT TRANSPORT DISTANCE, MILES	ALTERNATE DISPOSAL METHOD	COMMENTS	CODE NUMBER
...	...	...	...	Yes	IND	...	No	...	none	4	PCL,AS	infin	1	Yes		A3-130
...	...	0	none	Yes	IND	none	No	none	none	1.5	PCL,TF	none	2.5	No		A3-515
43	31	0.5	pH	Yes	IND	SS TDS BOD	Yes	LAB PPC	PS	6	PCL,AS	none	1	Yes	User Treatment: shock chlorination, pH adjust., corrosion inhibitor	C1-160
300	38	2	TURB pH LAB	Yes	IRR IND	BOD SS PO_4 MBAS	Yes	LAB	PS	2	PCL,TF, CCOAG,pH, CADS, MMF	3	3	No	User Treatment: Cold lime, Filt., Carbon adsorption	C2-186
1.33	...	0	...	Yes	IND	...	Yes	none	PS	...	PCL, TF(88%) AS(12%)	75	5	Yes	User Treatment: sedimentation, chlor., screening	M2-130
3.33	0	...	none	Yes	IND	...	...	...	PS	...	...	...	...	...		M4-510
20	42.3	0	LAB Cl_2	No	IND IRR	BOD SS	Yes	LAB	PS	10	PCL,TF	none	1	Yes	User Treatment: Cold lime clarif.	N2-471
30	64	0	none	Yes	IND IRR	BOD SS	Yes	LAB	PS	12	PCL,TF	6	1.5	Yes	User Treatment: Cold lime clarif.	N2-470
7	5	...	...	...	IND	...	Yes	LAB	PS	0.5	PCL,AS	none	2	Yes	User Treatment: Chem. clarif.	O2-250
80 90	145	0	TURB CON pH Cl_2	Yes	IND IRR	BOD SS	Yes	LAB	PS PrW	15	PCL,AS	18	10	Yes	Multiple users graduated charges User Treatment: cold lime, Alum floc., Clar., Soft.	T2-115
79	14.4	1	none	Yes	IND	TDS PO_4 Hard.	Yes	LAB	PS	1.4	PCL,AER	1	2	Yes	User Treatment: Hot lime, Hot zeo., Deaer., Anth. filt	T2-140
80	10.8	67	...	Yes	IND	SS TDS PO_4	...	LAB	PS	...	PCL,AS	10	2	Yes	User Treatment: Shock chlorin., pH adjustment	T2-202
119	42.7	1	Cl_2	Yes	IND IRR	BOD SS Cl pH PO_4	Yes	LAB	PS	12	PCL,AS	none	1-3	Yes	User Treatment: Cold lime, pH adjustment, Anth-Filt., Rev. Osmos., Zeolite	T2-497
125	250	0	LAB	Yes	IND	Alk Hard. Ca Mg PO_4	Yes	LAB	PrW	8	PCL,AS	15	0.5	Yes	User Treatment: Lime, Recarbonation, Zeolite	T2-575

QUALITY SAFEGUARDS	
AUTO	Automatic Testing
PPC	Pre & Post Chlorination
LAB	Regular Lab Testing
ST	State Testing Only
TREATMENT PROCESSES	
-PRIMARY TREATMENT	
PCL	Primary Clarification
RSL	Raw Sewage Lagoon
-SECONDARY TREATMENT	
AS	Activated Sludge
AER	Aeration Only
TF	Trickling Filter
CCOAG	Chemical Coagulation
OXPD	Oxidation Ponds
-TERTIARY TREATMENT	
ANTH	Anthracite Filter
MMF	Mixed Media Filter
SF	Sand Filter
CADS	Carbon Adsorption
CCOAG	Chemical Coagulation
DAER	Deaeration
IE	Ion Exchange
LCOAG	Lime Coagulation
pH	pH Adjustment
POL	Polishing Ponds
RO	Reverse Osmosis

Table 26. MAJOR INDUSTRY CLASSIFICATIONS USING MUNICIPAL WASTEWATER

Industry	Number of plants	Percent of total volume reused
Basic Metal Manufacturers	1	74
Power Generation	7	20
Petro-Chemical	5	5
Mining and Ore Processing	2	1

Table 27. TYPE OF INDUSTRIAL REUSE IN THE UNITED STATES

Type of use	Number of plants(1)	Percent of total	Reuse volume (mgd)
Boiler feed	3	17	1
Process	3	17	1
Cooling	12	66	154

(1)More than 15 because several reusers use municipal effluent for more than one use.

Table 28. MUNICIPAL EFFLUENT QUALITIES TO INDUSTRIAL REUSE IN THE UNITED STATES

PARAMETER	INDUSTRIAL USER AND APPLICATION			
	Bagdad Copper Corp. Bagdad, Arizona	El Paso Products Company, Odessa, Texas	City of Burbank, Calif.	City of Colorado Springs, Colorado
	Process	Cooling & Boilers	Cooling	Cooling (R&D)
BOD, ppm	14	10	2	8
SS, ppm	100	10-15	2	2
TDS, ppm	100	1300	500	650
Na, ppm	18	...	88	50
Chlorides, ppm	12	250	82	20
pH	6.8	7.4	7.2	6.9
Coliforms, MPN per 100 ml	...	6×10^5	0-20	225
Total Hardness	...	240	160	240
PO_4, ppm	...	44	20	1
Organic N, ppm	...	...	39	1-5
Heavy Metals, ppm	...	...	trace	trace
Color, units	...	...	...	5
MBAS, ppm	...	...	...	0.15
NH_3, ppm	...	...	...	27
NO_3, ppm	...	18	...	0.5

Table 28. (Continued)

PARAMETER	INDUSTRIAL USER AND APPLICATION			
	Bethlehem Steel Corp. Baltimore, Maryland	Dow Chemical Company Midland, Michigan	Nevada Power Co. Sunrise Station Las Vegas, Nevada	Champlin Refinery Enid, Oklahoma
	Cooling & Process	Cooling	Cooling	Cooling
BOD, ppm	46	20-30	21	31
SS, ppm	44	20-30	18	32
TDS, ppm	450	400-500	980-990	600
Na, ppm	75	...	...	...
Chlorides, ppm	100	200-300	...	...
pH	7.0	7.6	7.6	7.4
Coliforms, MPN per 100 ml	5×10^6	< 1000	...	...
Total Hardness	...	...	...	...
PO_4, ppm	12	...	15-20	...
Organic N, ppm	...	...	...	...
Heavy Metals, ppm	trace	none	...	...
Color, units	...	...	...	...
MBAS, ppm	...	...	...	...
NH_3, ppm	...	...	...	...
NO_3, ppm	4	...	1.0-3.4	...

Table 28. (Continued)

PARAMETER	INDUSTRIAL USER AND APPLICATION			
	Southwestern Public Service Co. & Texaco, Inc. Amarillo, Texas	City of Denton Denton, Texas	Southwestern Public Service Co. Lubbock, Texas	Cosden Oil & Chem. Co. Big Spring, Texas
	Cooling	Cooling	Cooling & Boilers	Boilers
BOD, ppm	10	10	18	35
SS, ppm	15	38	20	10
TDS, ppm	1400	127	1650	960
Na, ppm	300	...	450	...
Chlorides, ppm	300	70	460	...
pH	7.7	7.2	7.8	7.0
Coliforms, MPN per 100 ml	none	16,000	...	...
Total Hardness	...	...	...	...
PO_4, ppm	...	...	30-40	...
Organic N, ppm	...	...	...	...
Heavy Metals, ppm	...	trace	...	...
Color, units	...	...	...	...
MBAS, ppm	...	...	...	...
NH_3, ppm	...	...	...	...
NO_3, ppm	...	...	...	...

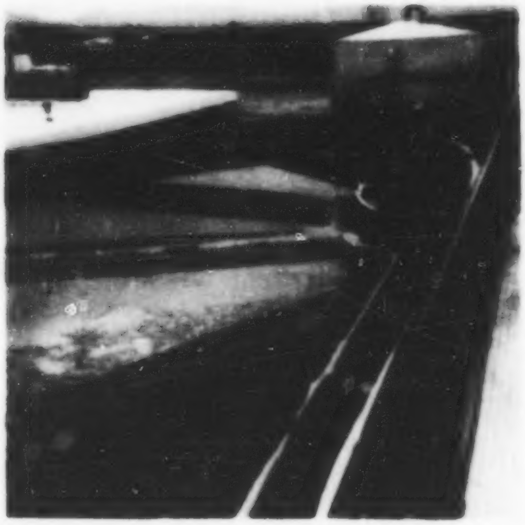

FIGURE 17

COLD LIME CLARIFIER TO TREAT REUSED WASTEWATER FOR COOLING TOWER MAKE-UP. THE NEVADA POWER CO., LAS VEGAS, NEV.

FIGURE 18

COLD LIME CLARIFIER (BACKGROUND) AND ZEOLITE SOFTENERS TO TREAT TREAT WASTEWATER FOR COOLING TOWER AND BOILER FEED MAKE-UP.
EL PASO PRODUCTS, CO., ODESSA, TEXAS

Table No. 29 shows average sewage treatment plant effluent quality (as measured by BOD and suspended solids) versus the treatment required by the industrial plant to make the water suitable for cooling tower makeup. The table shows that superior quality sewage effluent, e.g., the city of Burbank, California, can be used successfully with only an increase in chlorine, acid, and corrosion inhibitors required to put the effluent on almost equal status with fresh water. If, however, the treated sewage effluent is of average quality or worse, then clarification treatment is necessary to remove suspended solids and organics prior to use.

Table 29. EFFLUENT QUALITY VERSUS USER TREATMENT REQUIRED FOR COOLING TOWER MAKEUP WATER

	Effluent quality mg/l			
Selected Users	BOD	SS	TDS	User treatment processes
City of Burbank, CA	2	2	500	Shock chlorination, pH adjustment, corrosion inhibitor
Nevada Power Co. Las Vegas, NV	20	20	1,000-1,500	Shock chlorination, lime clarification, pH adjustment, corrosion inhibitor
Southwestern Public Service Company Amarillo, TX	10	15	1,400	Lime clarification, pH adjustment, shock chlorination, corrosion inhibitor
City of Denton, TX	30	30	130	Shock chlorination, pH adjustment, corrosion inhibitor (Treatment insufficient for effluent of this quality)
El Paso Products Company Odessa, TX	10	13	1,300	Lime clarification, pH adjustment, filtration, softening.

Boiler Feed Makeup Water

The three industrial plants reporting the use of sewage effluent for makeup to boilers are as follows:

Cosden Oil and Chemical Company
Big Spring, Texas

El Paso Products Company
Odessa, Texas

Southwestern Public Service Company
Lubbock, Texas

Each of the users provides substantial additional treatment, the extent of which is dependent upon the type of boiler for which the makeup water is intended. Low pressure boilers successfully utilize effluents which have been clarified, softened, and reduced in phosphates. High pressure boilers require makeup water which has been given the additional treatment step of dissolved solids removal, or deionization. Table 30 tabulates the treatment processes and average results achieved by each user. For their high pressure boilers, Southwestern Public Service Company and El Paso Products produce water of less than 2 TDS. For their low pressure boilers, Cosden Oil and Chemical Company and El Paso Products do not reduce total dissolved solids in the reclaimed water prior to use.

In depth discussions of all facets of these three sophisticated industrial reuse operations are presented in Appendix A.

Processing Water

Three plants reported using reclaimed sewage effluent for processing purposes, all in the mining and steel making industries. These are:

Bagdad Copper Corporation
Bagdad, Arizona

Phelps Dodge Corporation
Morenci, Arizona

Bethlehem Steel Corporation
Baltimore, Maryland

The two Arizona plants utilize the sewage effluent in the mining of copper.

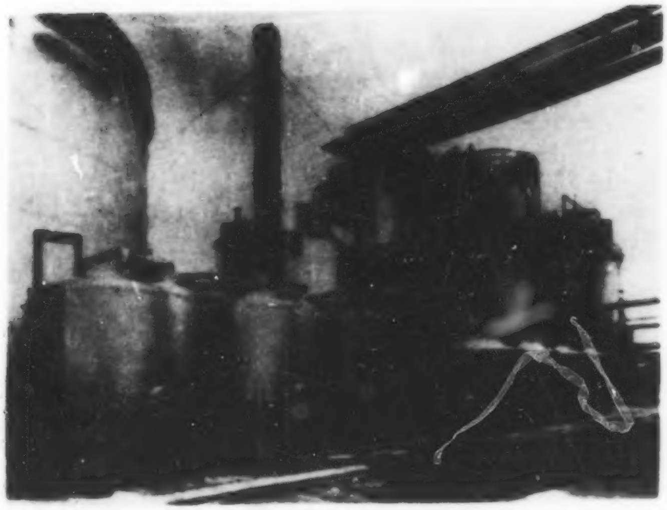

FIGURE 19
WATER TREATMENT EQUIPMENT TO PREPARE REUSED WASTEWATER FOR BOILER FEED MAKE-UP USE. HOT LIME CLARIFIER IN BACKGROUND AND ZEOLITE SOFTENERS IN FOREGROUND. THE COSDEN OIL AND CHEMICAL CO., BIG SPRING, TEX.

Table 30. COMPARISON OF TREATMENT PROCESSES UTILIZED FOR PRODUCING BOILER FEED MAKEUP WATER FROM MUNICIPAL SEWAGE EFFLUENT

Company and boiler pressure	Treatment processes	Product water quality, in ppm as $CaCO_3$
Cosden Oil and Chemical Company, Big Spring, TX (175 psig boilers)	Hot process lime clarification, anthracite filtration, hot zeolite softening, and deaeration.	TDS, 443 hardness, 0-2
El Paso Products Company Odessa, TX (200 psig boilers)	Cold lime clarification, recarbonation, anthracite, filtration, zeolite softening, and deaeration.	TDS, 1,000 hardness, 0-2
El Paso Products Company Odessa, TX (650 psig boilers)	All of above for low pressure boilers plus demineralization through cation and anion exchangers.	TDS, 0-2 hardness, 0
Southwestern Public Service Company Lubbock, TX (1,500 psig boilers)	Cold lime clarification, pH adjustment, reverse osmosis, followed by demineralization with cation and anion exchanges, and a mixed bed exchanger for final polishing.	TDS, 0-1 hardness, 0

Bagdad Copper Corporation pumps an average of 0.2 mgd of secondary treated effluent to its' tailings pond, where it is diluted approximately 20:1 with fresh water and used for milling of copper. Most domestic copper ore consists of low grade copper sulfides that are concentrated by flotation. Water for this purpose may be highly mineralized but it should be free of acid, mud, slime, and particularly petroleum products that adhere to ore and change its specific gravity. Later in this process, water is required for a leaching step where low pH and alkalinity are desirable.

The Phelps Dodge Corporation plant in Morenci uses 0.6 mgd of primary treated domestic sewage effluent from the town of Morenci. The sewage effluent is first percolated through the mine leach dumps collecting copper values. The pregnant leach solution is then pumped to the precipitation plant where it is reacted with recycled tin cans, removing the copper. The precipitation plant wastewater is then recycled back to the leach dump.

Bethlehem Steel Corporation uses the bulk of its' 170 mgd inflow of treated sewage effluent for cooling purposes but small amounts are also used for a variety of processes within this fully integrated iron and steel plant. Specific uses include gas cleaning, quenching, mill roll cooling, bearing cooling, process temperature control, direct process, de-scaling systems, mill hydraulic systems. fire protection, air conditioning, and road equipment washing.

Reported details of effluent quality utilized by all three of these process water users was given in Tables 25 and 28.

An additional use of reclaimed sewage for industrial processes should be mentioned. Three petro-chemical plants, as described in the previous section use sewage effluent for boiler feed makeup water. The steam from these boilers, and boiler blowdown, is used for a variety of process purposes within the plants.

Transport distances are often an important consideration in the feasibility of wastewater reclamation. Figure 20 shows the distances of various industrial users from the municipal suppliers. In all reported cases the user has been responsible for financing the effluent transport facilities.

Storage facilities for the reclaimed effluent were constructed by eight of the industrial reusers. Figure 21 illustrates the range of storage facility sizes.

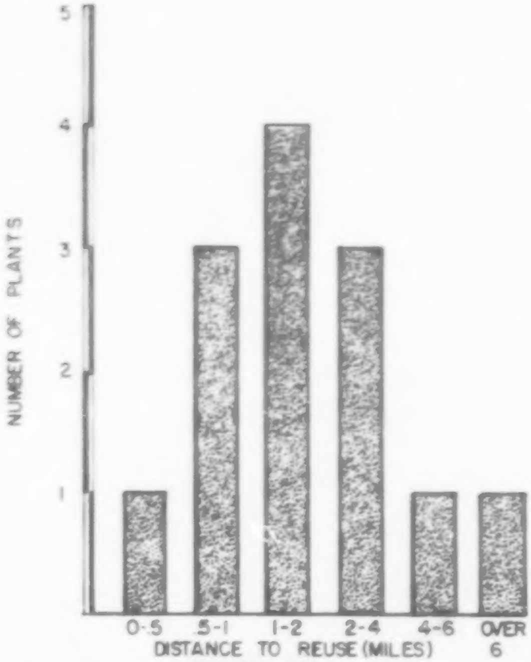

FIGURE 20
TRANSPORT DISTANCE FROM TREATMENT PLANT TO INDUSTRIAL REUSE

ECONOMICS OF INDUSTRIAL WATER REUSE

Economics is the prime motivating force of industry and the use of reclaimed wastewater is governed by the cost of alternate water supply procurement and treatment. In locations where public water supplies of good quality and quantity are available at low cost, treatment and reuse of renovated water by industry has not been economically attractive. Thus, it is not surprising that most industrial users of treated municipal effluent are in the semi-arid southwestern states where water costs are relatively high and water quality tends to be poorer in terms of TDS and hardness.

Several of the industrial plants do not have an adequate alternate source of water and are strongly dependent upon their sewage effluent supply. One example of such a situation is Southwestern Public Service Company's power plant in Amarillo, Texas. The public fresh water supply is limited and reclaimed effluent supplies 100% of their cooling water needs. See Appendix A for discussion of the Amarillo operation. Most of the other plants, however, have chosen to use reclaimed water because it is the cheapest source to serve their needs.

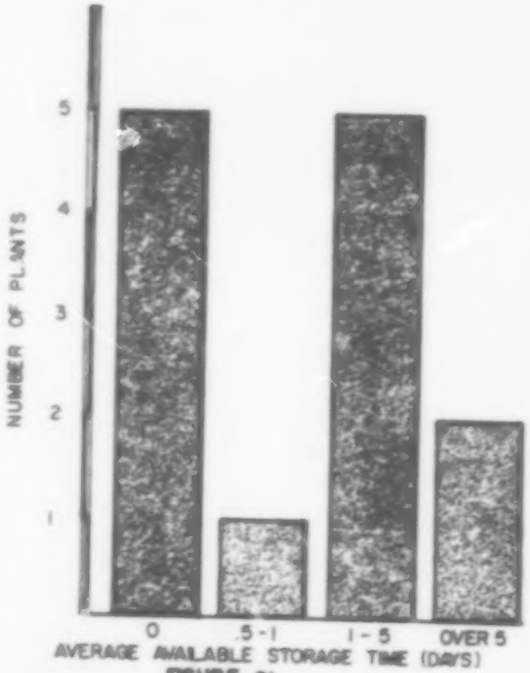

FIGURE 21
STORAGE CAPACITY OF INDUSTRIAL WATER SUPPLY FACILITIES

The cost of reclaimed water may be divided into two parts. First, the cost of procuring the reclaimed water, including payments to the municipality, construction of effluent transportation facilities, and all other costs required to deliver the effluent to the industrial plant site.

Second, the cost of treating the reclaimed water to make its' quality suitable for the intended use.

When comparing reclaimed water to fresh water, the cost of procuring reclaimed water is virtually always less, however, the cost of treatment is usually more. Table 31 shows reported procurement costs and user treatment costs for industrial plants. (In some cases, it was not possible to obtain information pertinent to user treatment costs because of company policy discouraging release of cost information.)

The total cost to the industry of procurement and additional treatment varies from nothing to $821 per million gallons.

The purchase price for the municipal effluent is sometimes tied to the cost of municipal sewage treatment, but availability of water in the area, local political situations, quality of the effluent, and other factors in some cases have significant effect. Disregarding Colorado Spring, which is a pilot operation, the range in purchase price of municipal effluent to industrial users is nothing to $144/MG with a median of $79/MG.

Additional treatment costs generally comprise the largest portion of the cost of reclaimed water to industry. The treatment costs depend upon the end use quality required, the quality of the sewage effluent, the degree of treatment required, the quantity of water treated, and other factors. For cooling water use in recirculating systems, the reported industry treatment costs varied from $100/MG to $550/MG. The lower cost is for treatment of exceptionally high quality effluent produced at Burbank, California, and the higher cost is for a very sophisticated reclaimed water treatment system at Odessa, Texas.

Both the exceptional secondary treatment at Burbank and the extensive tertiary system at Odessa, Texas, are discussed as field investigations in Appendix A.

For boiler feed makeup water use, Cosden Oil and Chemical Company reported treatment costs of $742/MG. Treatment costs incurred at other plants treating a portion of the effluent for boiler feed makeup water are estimated by SCS Engineers to be in the range of $500/MG to $1,000/ MG.

In this economics section primary emphasis has been made on the costs to the users. Various aspects of treatment costs incurred by the municipalities supplying the effluent were also summarized. None of the municipalities provided more treatment than would be necessary for discharge to surface waters. With only 15 plants represented, there is limited statistical significance to the summary figures which are as follows:

Table 31. INDUSTRIAL USER COSTS FOR RECLAIMED WASTE

USER	COST TO PROCURE EFFLUENT ($/MG)	USER TREATMENT COST ($/MG)	TOTAL EFFLUENT COST ($/MG)
Bagdad Copper Corp. Bagdad, Arizona	0	0	0
Phelps Dodge Corp. Morenci, Arizona	0	0	0
City of Burbank California	43	100	143
City of Colorado Springs Colorado	320	...	...
Bethlehem Steel Corp. Baltimore, Maryland	1.33(avg)	N/A	N/A
Dow Chemical Co. Midland, Michigan	3.33(avg)	N/A	N/A
Nevada Power Co. Las Vegas, Nevada	25	193	225
Champlin Refinery Enid, Oklahoma	7	N/A	N/A
Southwestern Public Service Co. Amarillo, Texas	80	160	240
Texaco, Inc. Amarillo, Texas	90	194	284
Cosden Oil & Chemical Co. Big Spring, Texas	79(avg)	742	821
City of Denton Texas	80	100	180
Southwestern Public Service Co., Lubbock, TX	144	160	304
El Paso Products Co. Odessa, Texas	125	550	675

- Municipal treatment costs and revenues for industrial uses, Figure 22.
- Effect of effluent volume on municipal treatment costs for industrial reuse, Figures 23 and 24.
- Effect of plant effluent volume on industrial users charges, Figure 25.
- User charges for industrial reuse relative to levels of treatment, Figure 26.
- User charges for industrial reuse relative to TDS and BOD concentrations, Figures 27 and 28.

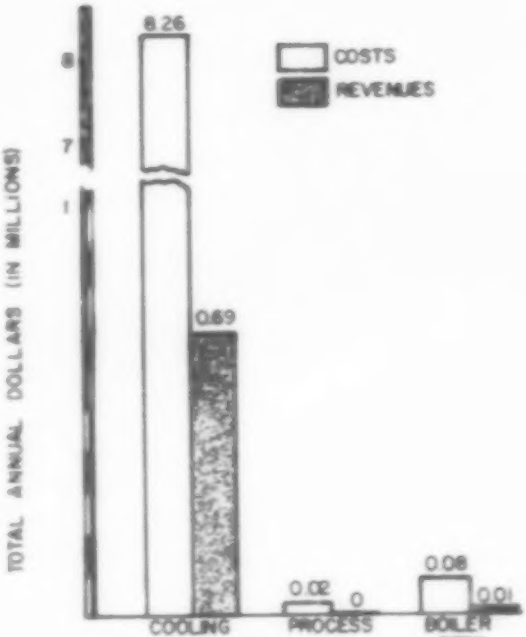

FIGURE 22

MUNICIPAL TREATMENT COSTS AND REVENUES FOR INDUSTRIAL USES

As with irrigation reuse, the revenue received by the municipalities from industrial reusers is less than the cost of treatment to the municipality. However, in all cases the municipality would have had to provide equivalent treatment prior to discharge in any case, so any revenues for sales of effluent are a bonus to the local municipal taxpayers.

Treatment costs per unit volume treated decreases, as volume increases, which is expected.

Corrolations between municipal effluent quality and cost to the user were as expected when measured by BOD, i.e. costs of low BOD effluent is more than high BOD effluents. When quality is measured in TDS, however, the cost relationship is contrary to what would be expected, i.e. the wastewater with high TDS sold for a higher price than the low TDS wastewater. This apparent incongruity is caused by the small sample of plants being considered, and the many factors influencing costs other than effluent quality. In the desert, even poor quality water is at a premium.

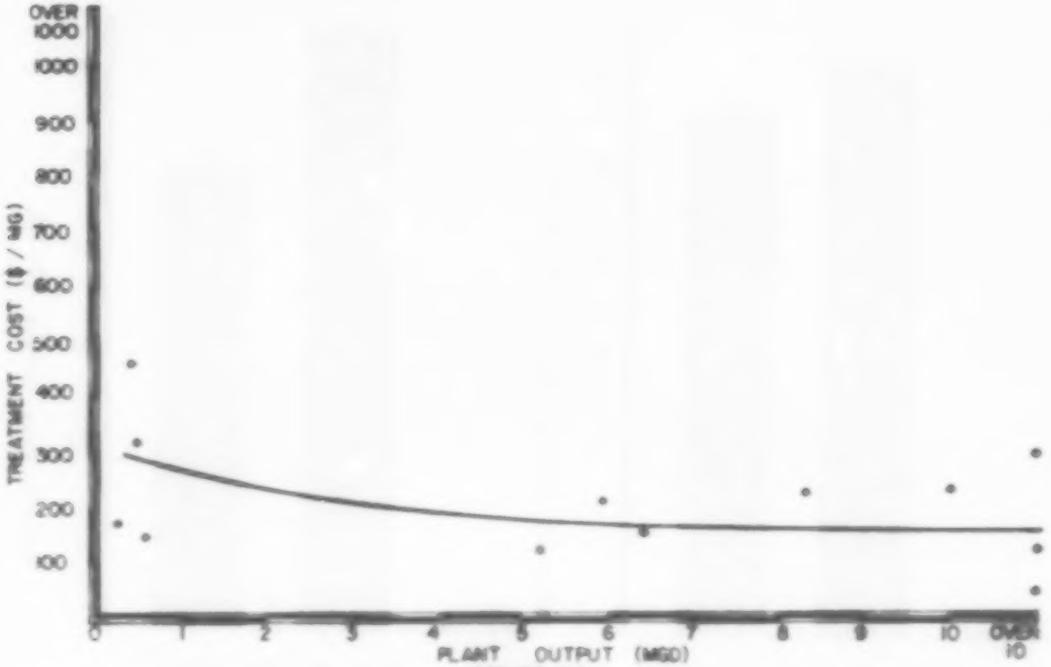

FIGURE 23
EFFECT OF EFFLUENT VOLUME ON TREATMENT COSTS FOR INDUSTRIAL REUSE
(INCLUDING CAPITAL AMORTIZATION)

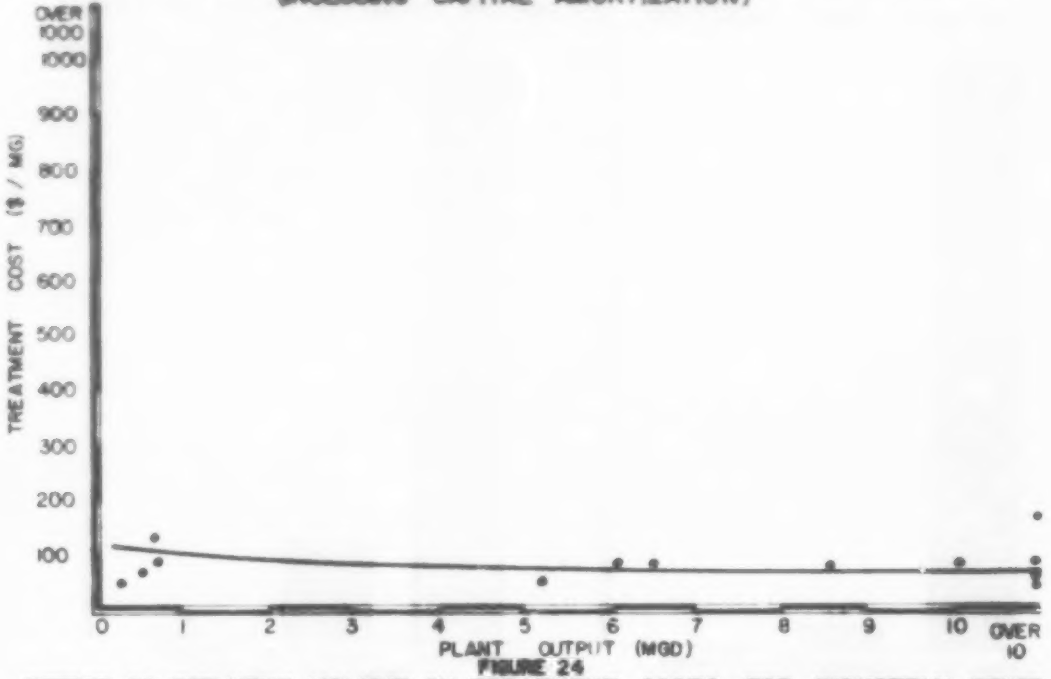

FIGURE 24
EFFECT OF EFFLUENT VOLUME ON TREATMENT COSTS FOR INDUSTRIAL REUSE
(EXCLUDING CAPITAL AMORTIZATION)

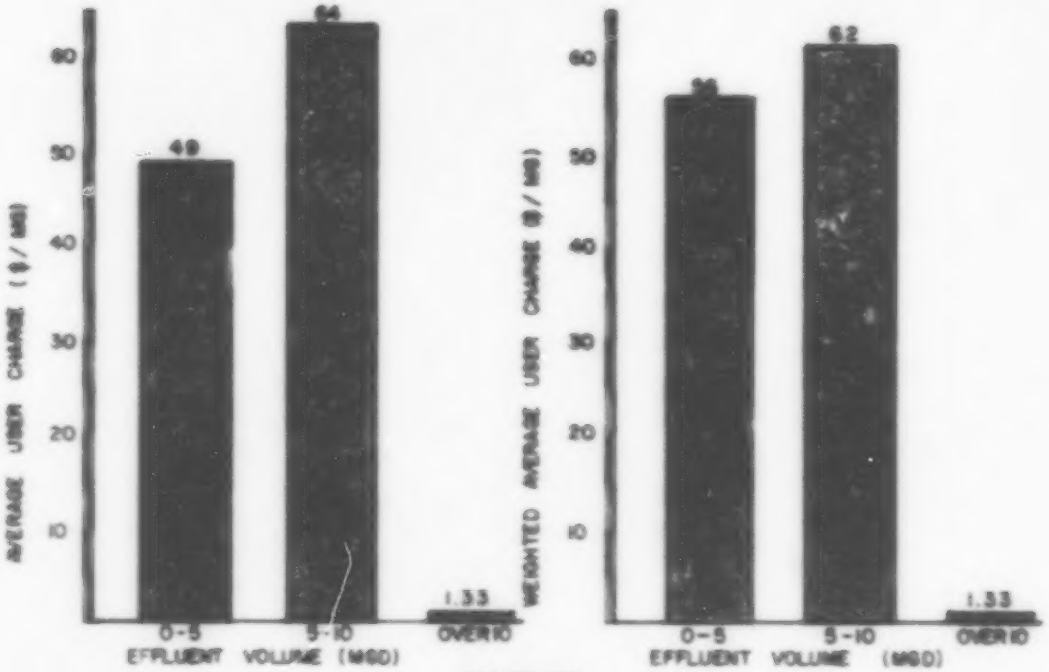

FIGURE 25

EFFECT OF PLANT EFFLUENT VOLUME ON INDUSTRIAL USER CHARGES

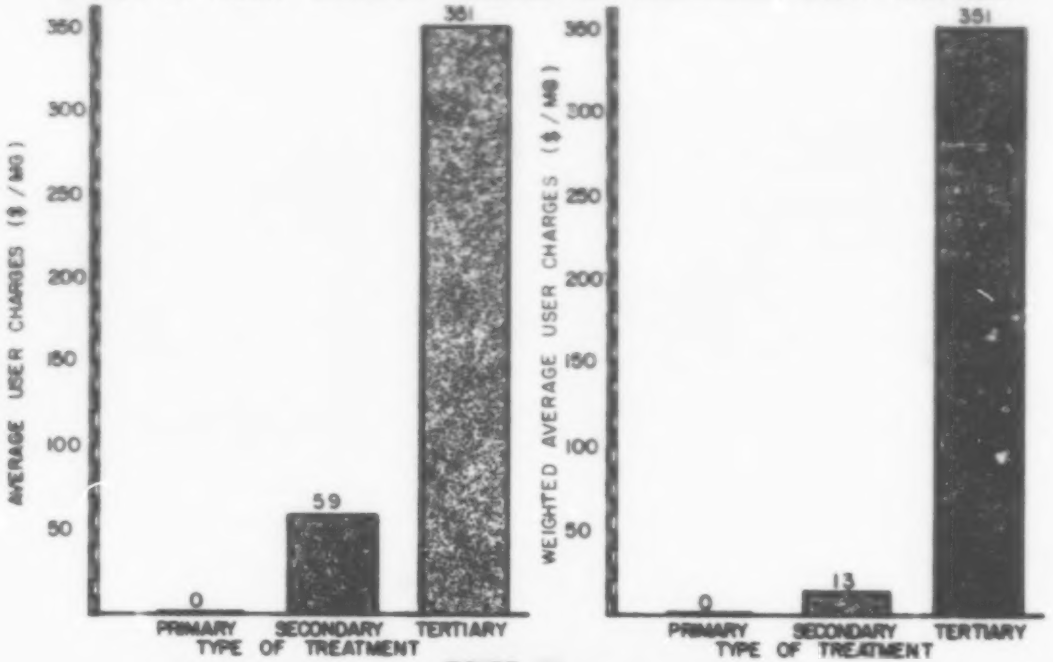

FIGURE 26

USER CHARGES FOR INDUSTRIAL REUSE RELATIVE TO LEVELS OF TREATMENT

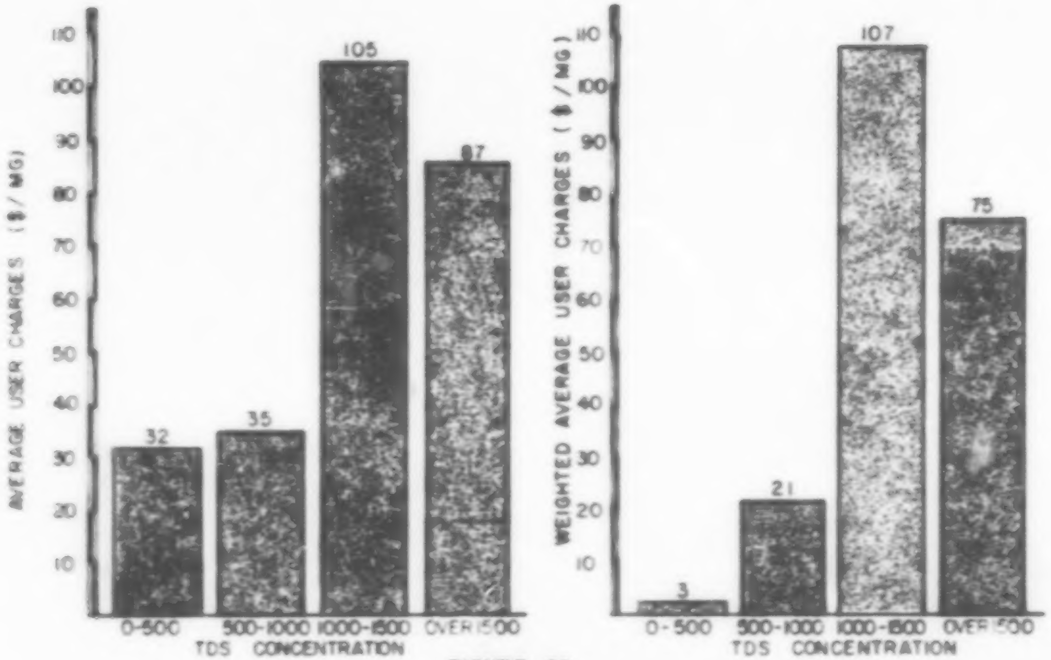

FIGURE 27
USER CHARGES FOR INDUSTRIAL REUSE RELATIVE TO TDS CONCENTRATIONS

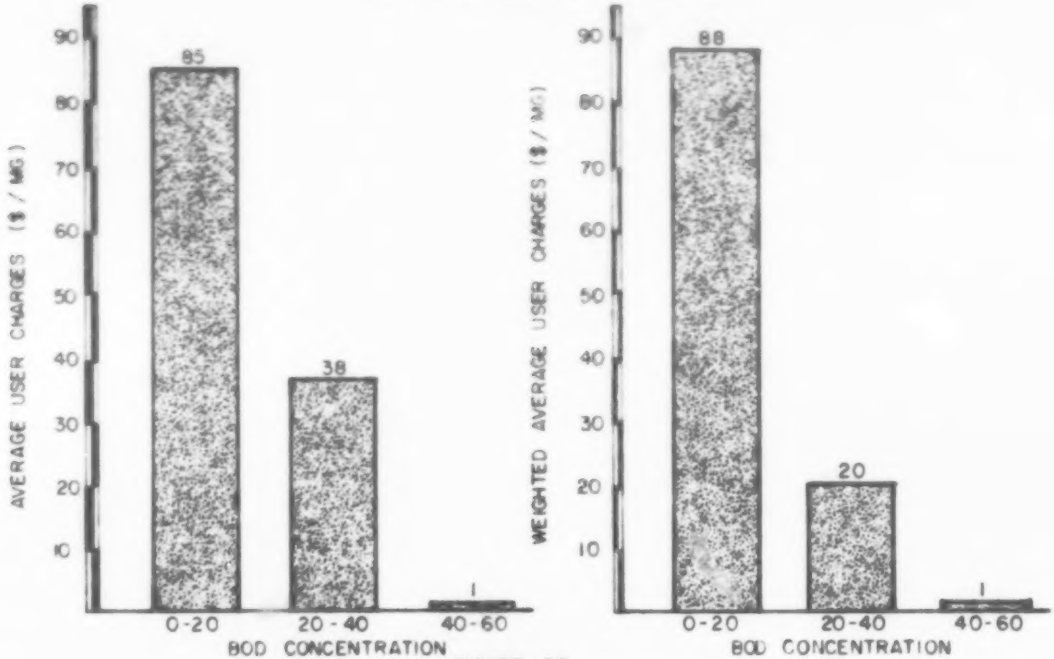

FIGURE 28
USER CHARGES FOR INDUSTRIAL REUSE RELATIVE TO BOD CONCENTRATIONS

SPECIFIC REFERENCE BIBLIOGRAPHY

FOR CHAPTER III

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2. FWPCA, Water Quality Criteria, April 1968.

3. Petrasek, Albert C., Esmond, Steven E. and Wolf, Harold W., Municipal Wastewater Qualities and Industrial Requirements, Paper presented at ASCHE meeting, Washington, D.C., April 1973.

4. Schmidt, Curtis J., The Role of Desalting in Providing High Quality Water for Industrial Use, Office of Saline Water Contract Report No. 14-30-2776, Oct. 1972.

SECTION IV

RECREATION REUSE

INTRODUCTION

Recreational uses of renovated wastewater include the following:

- Recreational lakes without sanctioned boating, fishing, or body contact, but with possibility of some inadvertent public contact. For example, lakes with shoreline picnic areas. It is assumed there is little significant risk of injestion.
- Recreational lakes with boating and fishing allowed, but no swimming. It is assumed that there is a significant risk of injestion and that the fish will be eaten by the fishermen.
- Recreational lakes with swimming, i.e., total immersion.
- Reclaimed wastewater lakes used only for incidental fishing.
- Irrigation of landscaping vegetation located in recreational areas.

Reclaimed wastewater lakes used only for incidental fishing are described in Chapter VI, and reuse for irrigation of recreational facilities (e.g., golf courses) is covered in Chapter II. This chapter will discuss three projects as listed in Table 32 which have made valuable contributions to the future development of recreational lakes composed of treated municipal wastewater.

The Tahoe and Santee projects are well publicized and were not field investigated as part of this study. Information on these two operations is thus based upon returned questionnaires and technical literature sources. The reuse program at Lancaster, California, is discussed in depth in Appendix A.

Table 32. RECREATIONAL REUSE OPERATIONS

Municipal plant location	Reuse volume (mgd)	Level of municipal treatment
Los Angeles, California (L.A. Sanitation District Lancaster Plant)	0.5	Tertiary
Santee, California (Santee County Water District	1.0	Tertiary
Lake Tahoe, California (South Tahoe PUD)	2.7	Tertiary

REQUIRED QUALITY CRITERIA

For recreational use, general water characteristics of concern include the following:

- Dissolved oxygen concentrations must always be above levels required to support game fish. Therefore, the organic strength, e.g., BOD, of the effluent must not exert an oxygen demand which lowers dissolved oxygen concentrations below acceptable levels. In addition, dissolved oxygen levels can be effected seriously by heavy algae growth or formation of an ice covering.

- Nutrients, e.g., nitrogen and phosphate compounds, stimulate unaesthetic algal growth and accelerate eutrophication.

- Ammonia in small concentrations can be very toxic to fish. The level of toxicity depends upon other water characteristics, including pH, dissolved oxygen and carbon dioxide concentrations.

- Fecal coliforms are indicative of the presence of pathogenic bacteria and viruses which can cause illness to persons coming in contact with the water.

- Toxic materials, e.g., heavy metals and chlorinated hydrocarbons, if present in water or bottom muds can be concentrated to deliterious levels in the aquatic food chain.

Water quality standards for municipal effluents supplying recreational lakes have thus been generally established to prevent introduction in detrimental qualities of the constituents listed above. In Table 33 are shown the standards set for the Lake Tahoe and Lancaster, California projects. To emphasize the stringency of the effluent standards shown in Table 33, a comparison may be made with Table 34 which shows the standards recommended by the California State Water Quality Control Board for water recreational areas where sewage is not being reclaimed. The water quality standards for recreational waters composed of reclaimed wastewater are obviously much more stringent than the quality recommendations for ordinary recreational waters.

CURRENT OPERATIONS

In the following three subsections the facilities at Santee, Lake Tahoe and Lancaster, California are briefly described. Certainly any municipality which is seriously considering the use of reclaimed effluent for a recreational lake involving body contact should contact these agencies operating the lakes directly in order to obtain complete information.

Sanitation Districts of Los Angeles County

A very interesting recreational lake project has been initiated by the Sanitation Districts of Los Angeles County utilizing oxidation pond effluent from their Lancaster, California water renovation plant. The project is described in detail in Appendix A. Over four years of study and pilot plant experimentation was conducted to determine optimum tertiary treatment design factors and the feasibility of economical renovation of oxidation pond effluent to meet quality standards. Much of the research and development was conducted under EPA grants, and is detailed in reports prepared for EPA.(2) The treated water is purchased by the county of Los Angeles for their Apollo County Park, an aquatic recreational park featuring boating and fishing.(3)

The tertiary processes at Lancaster as illustrated in Figure 24 include pre-chlorination, flocculation with alum, sedimentation, filtration, and disinfection. The product water quality objectives include the following criteria:

- Turbidity - 5.0 JTU's
- Coliform organisms - 2.2 per 100 ml

Table 33. WATER QUALITY REQUIREMENTS FOR SOUTH TAHOE AND LANCASTER

Parameter	South Tahoe and Lancaster	South Tahoe	—
	Lahontan RWQCB*	Alpine County	USPHS drinking water
Turbidity, JTU	3-10	5	5
PO_4, mg/l	0.1-0.5	no requirement	-
pH	6.5-7.0	6.5-8.5	6.0-8.5
BOD, ppm	5-10	<5	-
COD, ppm	45-75	<30	-
DO, ppm	7-15	-	4-7.5
Algae, counts/ml	0-10,000	-	-
Coliforms, MPN/100 ml	0-2.2	adequate disinfection	1
Temperature, °C	10-30	-	-
SS, ppm	10	<2	-
TDS, ppm	500-650	-	500
Ammonia Nitrogen, ppm	0.1-15.0	-	-
Organic Nitrogen, ppm	1.0-3.0	-	-
Nitrate Nitrogen, ppm	1.0-4.0	-	45
Total Nitrogen, ppm	3-20	-	-
Total Alkalinity, ppm	74-140	-	-
Hardness, ppm	85-110	-	-
MBAS, ppm	2-4	<0.5	-
Boron, ppm	0.8-1.4	-	-
SAR	5-7	-	-
Residual Chlorine, ppm	0.5-2.5	-	-
CO_2, ppm	1	-	-
ABS, ppm	7-15	-	0.5

*In California, quality standards for the plants discharging effluent to recreational lakes are set by regional water quality control boards.

Table 34. WATER QUALITY RECOMMENDATIONS FOR RECREATIONAL USES(1)

Parameter	Water contact		Boating and aesthetic	
	Noticeable threshold	Limiting threshold	Noticeable threshold	Limiting threshold
Coliforms, MPN per 100 ml	1,000*	#		
Visible solids of sewage origin	None	None	None	None
ABS (detergent), mg/liter	1*	2	1*	5
Suspended solids, mg/liter	20*	100	20*	100
Flotable oil and grease, mg/liter	0	5	0	10
Emulsified oil and grease, mg/liter	10*	20	20*	50
Turbidity, silica scale units	10*	50	20*	+
Color, standard cobalt scale units	15*	100	15*	100
Threshold odor number	32*	256	32*	256
Range of pH	6.5-9.0	6.0-10.0	6.5-9.0	6.0-10.0
Temperature, maximum ^{o}C	30	50	30	50
Transparency, Secchi disk, ft	-	-	20*	+

*Value not to be exceeded in more than 20 percent of 20 consecutive samples, nor in any 3 consecutive samples.

#No limiting concentration can be specified on the basis of epidemiological evidence, provided no fecal pollution is evident. (Note: Noticeable threshold represents the level at which people begin to notice and perhaps to complain. Limiting threshold is the level at which recreational use in surface waters would impede use.)

+No concentrations likely to be found in surface waters would impede use.

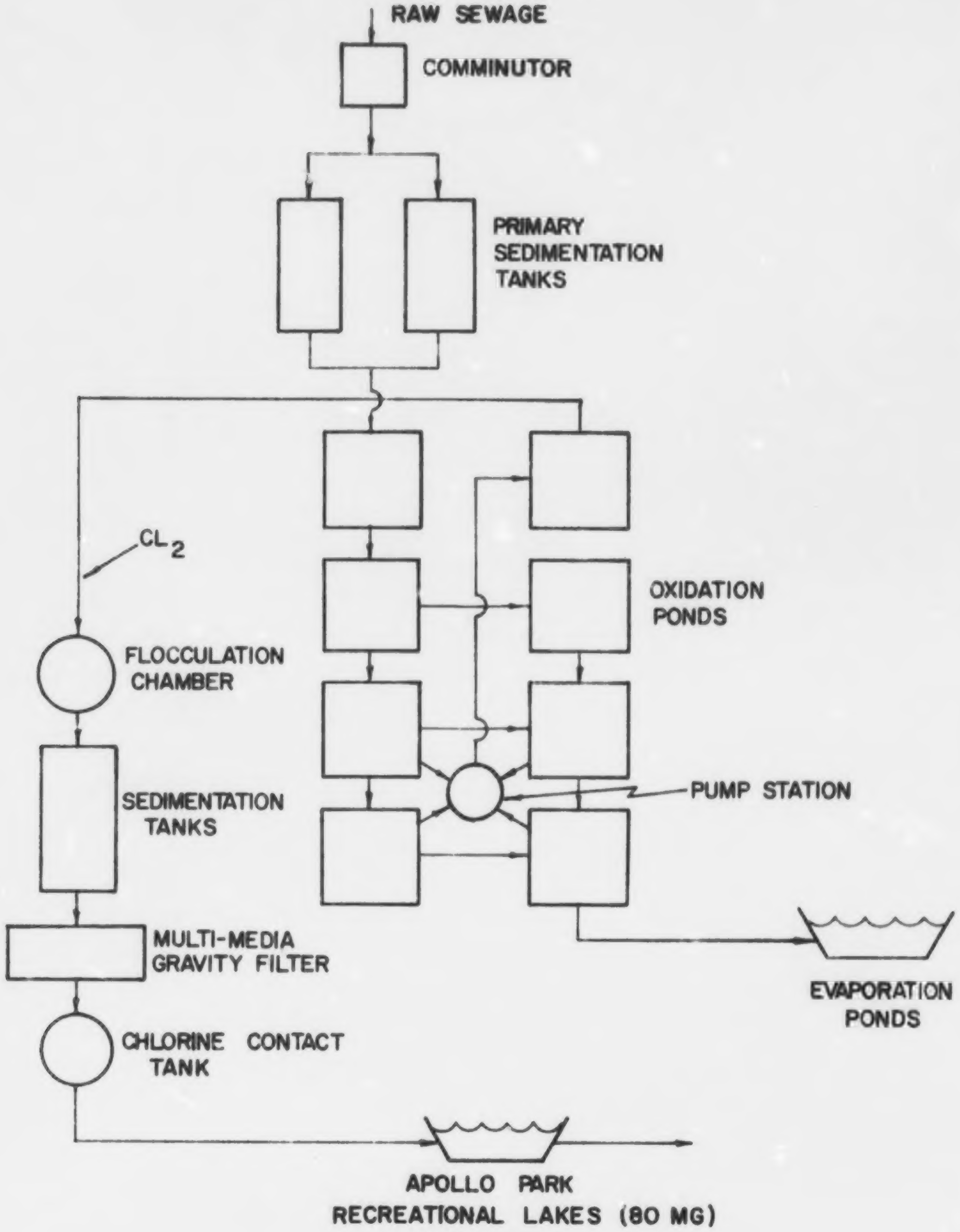
RAW SEWAGE
COMMINUTOR
PRIMARY SEDIMENTATION TANKS
CL_2
OXIDATION PONDS
FLOCCULATION CHAMBER
SEDIMENTATION TANKS
PUMP STATION
MULTI-MEDIA GRAVITY FILTER
EVAPORATION PONDS
CHLORINE CONTACT TANK
APOLLO PARK RECREATIONAL LAKES (80 MG)

FIGURE 29
WASTEWATER RENNOVATION PLANT NO. 14
(LANCASTER) L.A. COUNTY SANITATION DISTRICT

- Total phosphates - 0.5 mg/l
- Ammonia - 1.0 mg/l

Quality characteristics of the tertiary treated effluent and the lake water are summarized in Table 35, which shows that the effluent quality objectives have been accomplished. As detailed in the Appendix A case study, however, a careful program of oxidation pond management is required due to seasonal changes in the ammonia concentration and TDS of the oxidation pond effluent.

Low TDS, low ammonia water is stored at the treatment plant in the fall and used to dilute otherwise unsatisfactory effluent during the winter months. A heavy irrigation program is also encouraged at the receiving lakes to keep the water moving, thereby reducing the increase in dissolved solids in those waters.

During the winter months, green algae predominate in the oxidation ponds. These species of algae are easily removed in the tertiary plant by flocculation and filtration and cause no problems. However, with the advent of warmer temperatures blue-green algae (anacystic and oscillatoria) become prominent and initially caused difficulties. Blue-green algae do not flocculate and settle as readily as the greens and because of their size and shape, they pass through the dual media filter and cause an increase in turbidity. To counteract this problem, a pre-chlorination program prior to flocculation was initiated and the problem has been virtually eliminated. With pre-chlorination, the organisms flocculate and settle well and once settled they do not gas as they did previously.

South Tahoe Public Utility District

The best documented (4,5,6) tertiary treatment process in the nation is found at South Lake Tahoe Sanitary District, California where five tertiary treatment steps are combined to provide exceptionally high quality effluent. Figure 30 on the following page illustrates the treatment of activated sludge effluent by chemical coagulation for phosphate and nitrogen removal, filtration, carbon adsorption, and chlorination. This plant also utilizes advanced sludge handling techniques, lime recalcination and carbon reactivation. Much of the research and demonstration work has been funded by EPA.

Shortly before 1950 the regulatory agencies of Nevada and California responsible for protecting the waters of Lake Tahoe reached agreement that no sewage would be allowed to enter the surface waters of the Lake Tahoe Basin. Except

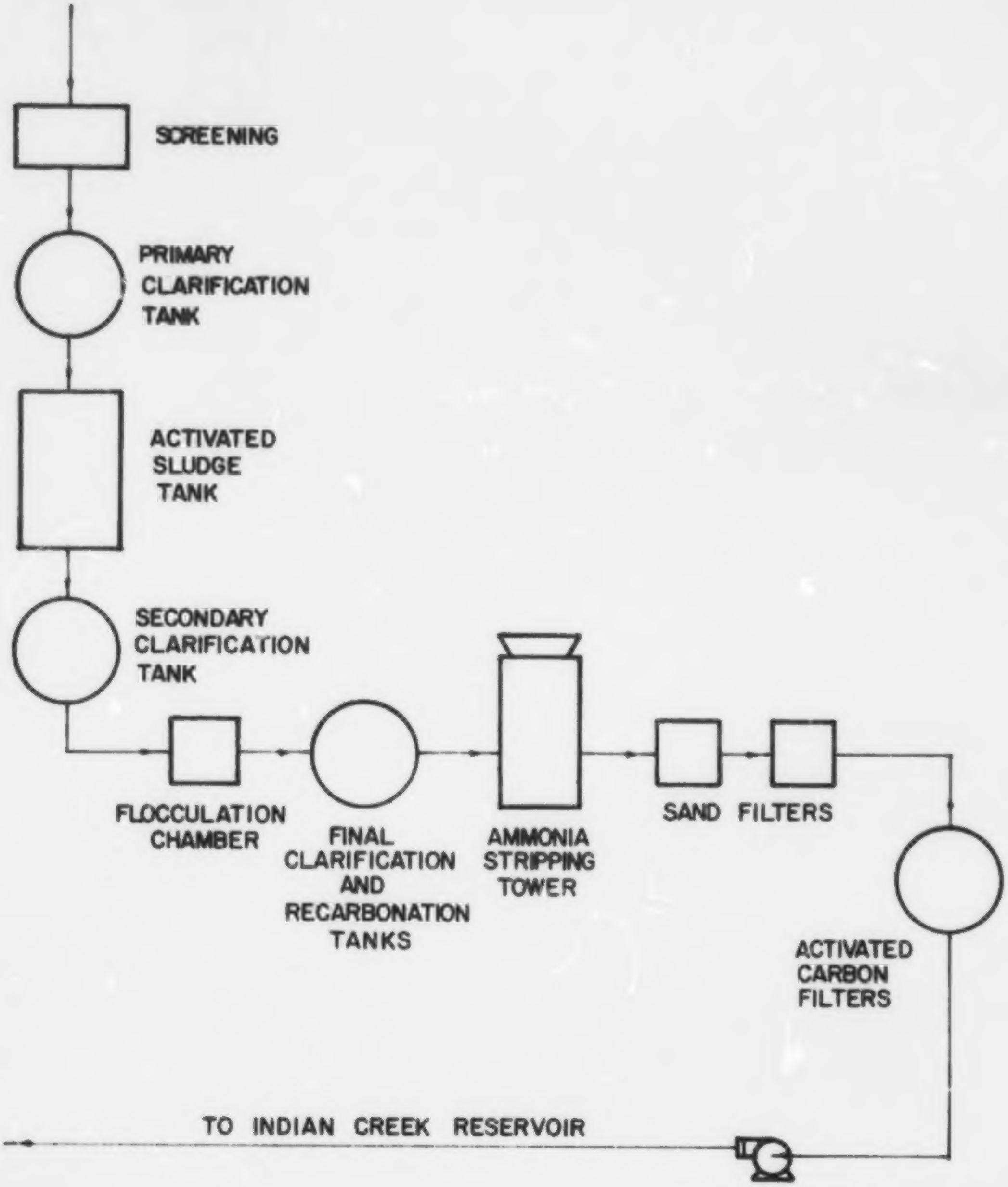
SCREENING
PRIMARY CLARIFICATION TANK
ACTIVATED SLUDGE TANK
SECONDARY CLARIFICATION TANK
FLOCCULATION CHAMBER
FINAL CLARIFICATION AND RECARBONATION TANKS
AMMONIA STRIPPING TOWER
SAND FILTERS
ACTIVATED CARBON FILTERS
TO INDIAN CREEK RESERVOIR

FIGURE 30

SOUTH TAHOE WATER RECLAMATION FACILITY

SOUTH LAKE TAHOE, CALIFORNIA

for accidents, this policy has been adhered to throughout a period of rapid growth in the Basin. In 1968 the District placed their tertiary system in operation and began to export water from the Tahoe Basin into Alpine County. The treated effluent is pumped 14 miles through a lift of 1,470 feet, and then flows through gravity pipeline an additional 13 miles to Indian Creek Reservoir. Indian Creek Reservoir has a capacity of 3,200 acre feet. It is approved for body contact sports (swimming) and is reported to boast excellent trout fishing.(7) Table 35 shows typical effluent characteristics of the South Tahoe treatment plant.

Santee County Water District

This project is justifiably famous for its' pioneering work in the reclamation of domestic sewage for recreational lakes. Since 1961, Santee has provided much of the research and development data utilized to answer questions regarding the potential health hazards involved in public use of recreational lakes composed of treated wastewater. The Santee lakes have been used progressively for recreational activities involving increased human contact as laboratory results and epidemiological information indicated that such activities could be conducted without health hazard. The lakes are now used for boating and fishing with associated activities along the shoreline but are not open for whole-body water contact sports. In 1965, an area adjacent to one of the lakes was equipped with a separate flow-through swimming basin which used reclaimed water that was given

FIGURE 31

RECREATIONAL LAKES OF RECLAIMED WASTEWATER AT SANTEE, CA.

additional treatment by coagulation, filtration, and chlorination.

Among the most significant data developed by the Santee project were studies of virus survival. The virus study(8) concluded that the oxidation pond and percolation zone were efficient in removing bacteria and virus. No virus were found in the recreational lakes or in the swimming pool. In concurrent studies,(8) no epidemiological evidence of illness was found.

As shown in Figures 32 and 33 effluent from the Santee activated sludge plant is discharged to a 30 MG oxidation pond. Effluent from the pond is the pumped one half mile to three acres of percolation beds located upstream from the recreational lakes. The down-canyon flow from the beds percolates horizontally underground through the natural sand and gravel strata for distances that have varied from 400 to 1,500 feet. The vertical drop is approximately 15 feet. The underground flow is intercepted by large collection ditches. Intercepted flow is essentially 95 percent wastewater except during periods of heavy rainfall. The collected water is chlorinated in a contact chamber prior to entry into the uppermost of four recreational lakes or to tertiary treatment at the swim basin described above. The four lakes are arranged in series and range in capacity from 12 to 18 MG and in surface area from 6 to 10 acres.

Plant Performances

Typical effluent quality is shown in Tables 35 and 36 for each of the three plants supplying reclaimed water for recreational lakes. While each plant meets most of its quality objectives the great majority of the time, specific problems have been encountered. Lancaster reports that the ammonia levels are occasionally excessive during the winter months while turbidity is consistently above limits. The Lancaster effluent also has a high chlorine residual and high carbon dioxide concentration, both of which drop to acceptable levels in the recreational lakes. The lakes, however, show excessive turbidity and total dissolved solids. These problems, and others discussed previously, cause the effluent to be substandard 15 percent of the time. The Santee County Water District reports that the TDS discharge requirement set by the Regional Water Quality Control Board has been difficult to meet. The high saline level of the local water supply is responsible for the situation. Also noted are algae blooms in the lakes, especially during the summer months.

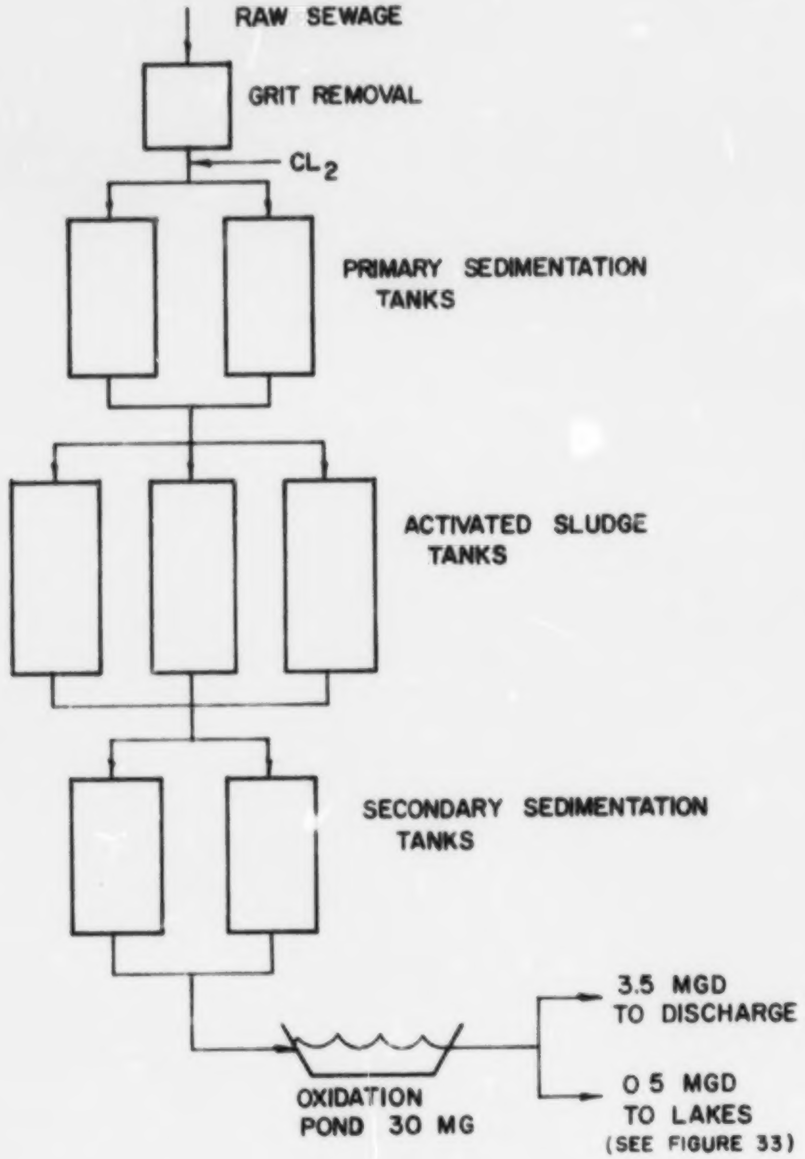
RAW SEWAGE
GRIT REMOVAL
CL2
PRIMARY SEDIMENTATION TANKS
ACTIVATED SLUDGE TANKS
SECONDARY SEDIMENTATION TANKS
3.5 MGD TO DISCHARGE
0 5 MGD TO LAKES (SEE FIGURE 33)
OXIDATION POND 30 MG

FIGURE 32
SANTEE COUNTY WATER
RECLAMATION FACILITY
SANTEE, CALIFORNIA

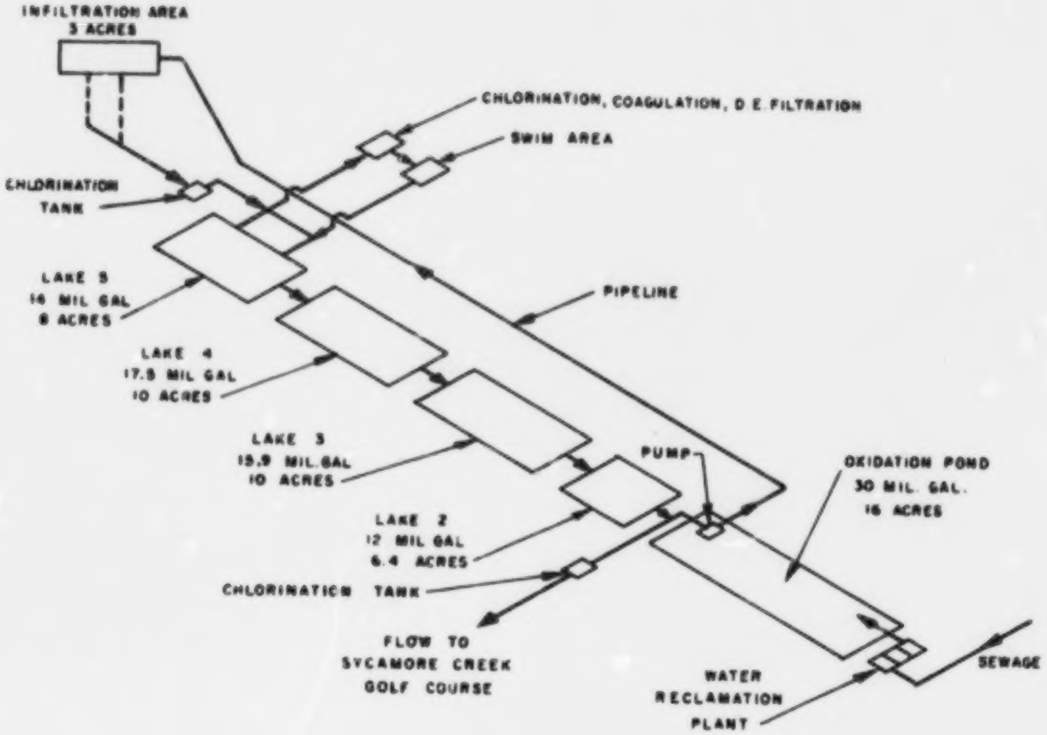
INFILTRATION AREA
3 ACRES
CHLORINATION, COAGULATION, D E FILTRATION
SWIM AREA
CHLORINATION
TANK
LAKE 5
14 MIL GAL
8 ACRES
PIPELINE
LAKE 4
17.5 MIL GAL
10 ACRES
LAKE 3
15.9 MIL.GAL
10 ACRES
PUMP
OXIDATION POND
30 MIL. GAL.
16 ACRES
LAKE 2
12 MIL GAL
6.4 ACRES
CHLORINATION TANK
FLOW TO
SYCAMORE CREEK
GOLF COURSE
WATER
RECLAMATION
PLANT
SEWAGE

FIGURE 33

ISOMETRIC SKETCH OF LAKE SYSTEM
SANTEE, CALIFORNIA

Table 35. TYPICAL PLANT PERFORMANCE SUPPLYING WASTEWATER FOR RECREATIONAL LAKES

PARAMETER	LANCASTER WATER RENOVATION PLANT			
	PLANT EFFLUENT	LAKE 1	LAKE 2	LAKE 3
Temp., ^{o}F	38	36	36	35
Turbidity, JTU	1.5	23	22	25
pH	6.15	7.70	8.59	8.62
TDS, mg/l	544	843	932	851
SS, mg/l	5	28	32	32
Alkalinity, mg/l $CaCO_3$	65.1	148	167	150
Boron, mg/l	0.74	1.33	1.52	1.29
CO_2, mg/l	67.58	2.64	0	0
Chlorine Demand/hr., mg/l	0	0.99	1.01	0.96
Chlorine Residual, mg/l	3.4	0	0	0
Total Hardness, mg/l $CaCO_3$	68	117	128	121
MBAS, mg/l	0	0.1	0.1	0.1
Ammonia Nitrogen, mg/l	1.0	1.0	1.2	1.2
Organic Nitrogen, mg/l	1.7	2.0	2.0	1.9
Nitrite Nitrogen, mg/l	0	0.02	0.03	0.03
Nitrate Nitrigen, mg/l	1.9	1.2	0.8	1.1
BOD, mg/l	0.4	2.2	1.4	1.9
Total COD, mg/l	35	45	51	49
DO, mg/l	12.4	10.5	11.7	12.1
Ortho Phosphate, mg/l	0.21	0.26	0.25	0.20
Total Phosphate, mg/l	0.29	0.38	0.43	0.40
Potassium, mg/l	16	20	19	18
Sodium, mg/l	158	238	239	237
Sodium Equiv. Ratio, % Na	79.5	78.6	77.3	78.2
Coliforms, MPN/100 ml	<2.2	<2.2	<2.2	<2.2

Table 35. (Continued)

Parameter	So. Tahoe P.U.D.		Santee Co. W.D.		
	Plant effluent	Indian creek resv'r	Ox. pond effluent	After infil- tration	Lakes system
Temp., ^{O}F		4-22			
Turbidity, JTU	0.3-0.5		30	5	0-20
pH	6.9-8.6	8.4	7.7	7.7	8.8
TDS, mg/l	250	120-416	1,168	1,150	1,150-1,600
SS, mg/l	0	3.4	8.6	5-10	
Alkalinity, mg/l CaCo$_3$	187-308	125	250	240	50-170
Boron, mg/l					
CO$_2$, mg/l			5.6	2.4	0
Chlorine Demand/hr., mg/l					
Chlorine Residual, mg/l	0.6-2.2		0	0	0.01
Total Hardness, mg/l CaCO$_3$	110-164		380	400	210
MBAS, mg/l	0.19-0.45				
Ammonia Nitrogen, mg/l	23.0-35.0	3.6	22.3	0.36	0.1-1.0
Organic Nitrogen, mg/l		0.9			
Nitrite Nitrogen, mg/l	0.01-0.27	0.2	0.02	0.01	0.01
Nitrate Nitrigen, mg/l	0.1-0.9	2.8	1.0	1.0	1.0
BOD, mg/l	0.7-3.2	6.6	5.0	3.5	
Total COD, mg/l	12.0-28.7	22		41	
DO, mg/l		9.3			6.0
Ortho Phosphate, mg/l		0.05			
Total Phosphate, mg/l	0.17-0.41	0.09	8.0	3.6	0.1-4.2
Potassium, mg/l					
Sodium, mg/l	<5			207	
Sodium Equiv. Ratio, % Na					
Coliforms, MPN/100 ml	<2			<2	<2.2
Ammonium & Ammonia Nitrogen	0.1-1.2	3.3-4.0			
Chlorides mg/l	30	21.8	230	250	270-480
Sulfates mg/l	15-36		450	340	380-575

Table 36. HEAVY METAL CONCENTRATIONS IN PLANT EFFLUENTS USED IN RECREATIONAL LAKES, mg/l

Parameter	So. Tahoe P.U.D.	Lancaster W.R.P.	Santee County W.D.	Maximum U.S.P.H.S. drinking water
Arsenic	<0.005	0	0	0.05
Chromium^{+6}	<0.0005	0	0	0.05
Copper	0.0116	0.04	0	1.0
Iron	<0.0003	0.22	0	0.3
Manganese	0.002	0.03	-	0.05
Selenium	<0.0005	0	-	0.01
Silver	0.0004	-	-	0.05
Zinc	<0.005	0.24	0	5.0
Bromine	0.065	-	-	-
Uranium	0.0015	-	-	-
Cobalt	0.00022	-	-	-
Cesium	0.000006	-	-	-
Mercury	<0.0005	-	-	-
Rubidium	0.010	-	-	-
Scandium	0.000001	-	-	-
Antimony	0.00044	-	-	-

The South Tahoe Public Utility District reports no adverse conditions in either the plant effluent or the reservoir in Alpine County since the installation of an ammonia stripping process. Prior to that, a major fish kill at Indian Creek Reservoir occurred during the winter of 1971. An 8 inch ice cover on the reservoir melted very rapidly releasing a surge of nutrients and NH_3 into the water and approximately 5 to 10 percent of the fish in the reservoir were killed.

Final disposal of the water following detention in the recreational lake is an important consideration in overall utilization by reuse. The one billion gallon capacity Indian Creek Reservoir retains water for an average period of 7 months between complete turnovers. Final disposal is to Indian Creek from which farmers extract a portion for their irrigation needs. Santee maintains an average 16 day retention followed by final disposal through turf irrigation and discharge to the San Diego River. The Lancaster Water Renovation Plant has no receiving stream for its final disposal, so it must depend upon irrigation practices to assimilate the stored effluent.

All three of the plants provide advanced laboratories equipped to perform the tests required to monitor treatment performance. Chemists have a program of routine sampling established for all the parameters described previously in this chapter. As exemplified by the Lancaster operation, sampling is necessary at both the plant effluent point and within the reservoir.

Unofficial Recreational Use

The operations describe in this chapter are plants officially supplying effluent for recreation. An unknown number of plants producing high quality effluent provide recreational water on an unofficial, informal or illegal basis. Figure 34 illustrates such a case where children have climbed a fence to frolick in the effluent from the Whittier Narrows Water Reclamation Plant in Los Angeles County.

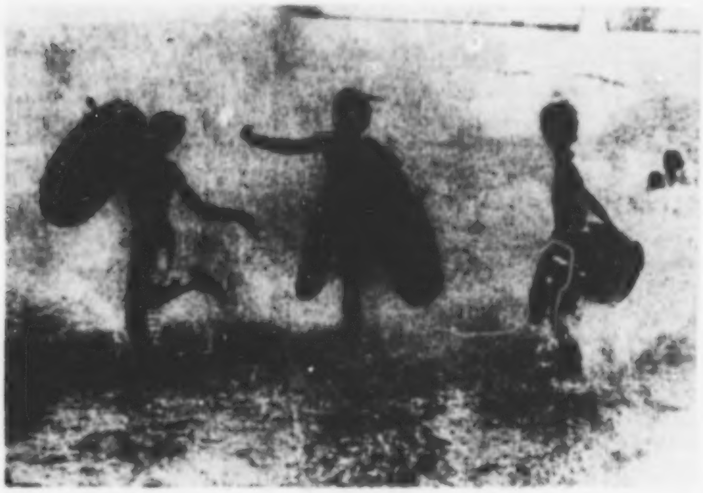

FIGURE 34

CHILDREN FROLIC IN TREATED EFFLUENT

The heavy use of municipal sewage ponds by ducks, and other game birds, has been reported. The ponds are thus contributing to wildlife conservation and American outdoor recreation. Thousands of these birds are killed and consumed annually by hunters. A public health concern exists since lead shot will drive bacteria from feathers into the body of the duck. Also, the ducks may build up high concentrations of toxic elements and organic compounds, if such deleterious compounds are significantly present in the sewage pond the ducks inhabit. No research into these potential health hazards has been reported.(9)

ANALYSIS OF CURRENT ECONOMICS

Table 37 summarizes treatment costs reported by the three plants supplying effluents used in recreational lakes. Of interest are the bottom lines of Table 37 which contrast the comparatively low cost of the Lancaster treatment operation relative to the more sophisticated operations at Tahoe and Santee. The Lancaster plant, which uses simple chemical flocculation and filtration following oxidation ponds, produces effluent for about $150/MG including amortization. Operating costs are also much less at Lancaster than at Tahoe or Santee.

A major reason behind the high cost of treatment at South Tahoe P.U.D. is that the present volume of 2.7 mgd is far below the plant design capacity of 7.5 mgd. The District believes its costs will be reduced to approximately $320/MG when the plant reaches full design capacity.

Table 37. TREATMENT COSTS REPORTED BY TERTIARY PLANTS SUPPLYING EFFLUENTS USED IN RECREATIONAL LAKES

Parameter	Plant							
	South Tahoe P.U.D.			Lancaster W.R.P.				Santee County W.D.
Year built	1959	1965	1967	1958	1959	1960	1969	1967
Original cost (millions)	2.0	1.0	2.5	.687	.063	.069	.248	2.0
Sewerage const. cost index ratio (Jan. 1972/yr built)	1.66	1.54	1.44	1.69	1.66	1.64	1.30	1.44
January 1972 equivalent cost	3.32	1.54	3.60	1.16	0.10	0.11	0.32	2.88
Annual capital amortization 5.5%-25 years	247,506	114,807	268,380	86,478	7,455	8,200	23,856	214,704
1971 annual operating costs								
. labor		-		30,503				78,040
. supplies		-		8,883				30,141
. utilities		-		12,634				43,175
. other		-		12,217				171,727
. total		238,600		64,237 (sec.) 28,273 (tert.)				323,083
Total annual cost including amortization		869,293		218,499				537,787
Annual effluent (mg)		986		1,460				1,205
Effluent cost w/amortization ($/mg)		882		150				446
Effluent cost w/o amortization ($/mg)		242		63				268

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CHAPTER V

DOMESTIC REUSE

INTRODUCTION

Great controversy surrounds the subject of domestic reuse of wastewater for potable purposes. A recent study in California,(6) documented public attitudes in that state toward various uses of reclaimed wastewater. It was found that opposition to the use of reclaimed water is generally dependent upon the likelihood or extent of personal contact. Non-potable domestic uses such as lawn irrigation and toilet flushing were opposed by less than 4 percent of the respondents, home laundry by 20 percent, and potable reuse was opposed by over 55 percent of all respondents.

It is not within the scope of this study to enter into the controversy over technical capability, health hazards or public acceptability of domestic reuse of reclaimed water. This chapter briefly describes the well known operation at Windhoek, South West Africa, which is the only current example of direct potable reuse of municipal wastewater. In addition, the non-potable domestic reuse program managed by the National Park Service at Grand Canyon National Park is discussed. The Grand Canyon operation is described in detail in Appendix A, Field Investigation Reports.

Table 38 summarizes treatment and volume reused for these systems.

Table 38. INVENTORY OF DOMESTIC REUSE OPERATIONS

Municipal Plant Location	Reuse Volume (mgd)	Level of Municipal Treatment
Windhoek, South West Africa	0.59	Tertiary
Grand Canyon, AZ (National Park Service)	0.03	Tertiary

One other documented example of potable reuse, although of short duration, was that at Chanute, Kansas.(5) A severe drought from 1952 to 1957 forced this town of 12,000 inhabitants to make almost direct potable use of the effluent from its sewage treatment plant during a 5 month period. When the Neosho River, the normal water source, went dry in the summer of 1956, chlorinated effluent from the secondary treatment plant was collected behind a dam in the river bed. The residence time in this pond was approximately seventeen days. The water was then coagulated, settled, filtered, and chlorinated at the water treatment plant for distribution to the community as the potable supply.

The tap water never failed to meet Drinking Water Standards. However, it had a pale yellow color, an unpleasant musty taste, and frothed when drawn into a glass. It was high in chlorides, sodium, total solids, and organic content. Coliform organisms were found on three different days, but MPN levels were within standards.

Algae were present from 2,000 to 45,000/ml. A few live, unidentified amabae and small nonpathogenic worms were recovered. No viruses were identified.

Public acceptance was poor and sales of bottled water flourished. Seventy private wells were drilled (although most of the water from this source was found too mineralized to be palitable).

One year later local and federal health authorities met with the local medical society. It was the consensus that no illness could be traced to the water supply, even though many patients blamed the water for illnesses they acquired.

Ten years later, Carl E. Workman, Superintendent of the Water Plant, stated in a telephone interview that apparently no chronic ill effects had ever been discovered due to the drinking of reclaimed water during the 5 month emergency period.

QUALITY CRITERIA

Criteria for the reuse of municipal wastewater for domestic purposes is recognized by authoritative sources to be lacking. The USPHS drinking water standards are ineffective in stipulating limits for treated wastewater constituents; the standards, in fact, exclude wastewater by definition.(1)

The operation at Windhoek, South West Africa is currently the only officially-recognized, full-scale potable reuse facility in the world; and, even at Windhoek, the treated wastewater is diluted 7.5 to 1 with fresh water before being supplied to the city.

The World Health Organization (WHO) sets the standards for the Windhoek water supply. Portions of the WHO standards and the USPHS Drinking Water Standards, are presented in Table 39.

Table 39. WHO AND USPHS DRINKING WATER STANDARDS

Parameter, mg/l	Regulatory Agency		
	WHO		USPHS
	Acceptable	Allowable	
pH	7.0-8.5	6.5-9.2	6.0-8.5
Color	5	50	15
Turbidity	5	25	5
TDS	500	1,500	500
Sulfates	200	400	250
Chlorides	200	600	250
Nitrates	-	45	45
Ammonium Nitrogen	0.5	-	-
Kjeldahl Nitrogen	1.0	-	-
COD	10	-	-
BOD	6	-	-
DO	-	-	4-7.5
ABS	0.5	1.0	0.5
Coliforms	-	-	1

The United States Environmental Protection Agency's "Policy Statement on Water Reuse" (July 7, 1972) states in regard to potable reuse as follows:

> "We do not have the knowledge to support the direct interconnection of wastewater reclamation plants into municipal water supplies at this time. The potable use of renovated wastewaters blended with other acceptable supplies in reservoirs may be employed once research and demonstration has shown that all of the following conditions would be met:
>
> a. Protection from hazards to health
> b. Offers higher quality than available conventional sources
> c. Results in less adverse ecological impact than conventional alternatives
> d. Is tested and supplied using completely dependable chemical and biological control technology

> e. Is more economical than conventional sources
> f. Is approved by cognizant public health authorities."

The joint AWWA-WPCF statement on domestic reuse is somewhat different from the EPA statement and reads as follows:

> "WHEREAS: Ever-greater amounts of treated wastewaters are being discharged to the waters of the nation and constitute an increasing proportion of many existing water supplies, and
>
> WHEREAS: more and more proposals are being made to introduce reclaimed wastewaters directly into various elements of domestic water-supply systems, and
>
> WHEREAS: the sound management of our total available water resources must include consideration of the potential use of properly treated wastewaters as part of drinking-water supplies, and
>
> WHEREAS: there is insufficient scientific information about acute and long-term effects on man's health resulting from such uses of wastewaters, and
>
> WHEREAS: fail-safe technology to assure the removal of all potentially harmful substances from wastewaters is not available,
>
> NOW THEREFORE BE IT RESOLVED: that the AWWA and WPCF do hereby urge the federal government to support immediate multi-disciplinary national effort to provide the scientific knowledge and technology relative to the reuse of water for drinking purposes in order to assure the full protection of the public health."

It is expected that more definitive quality standards for both potable and non-potable domestic reuse will be forthcoming.

ANALYSIS OF CURRENT PROCESS PRACTICES

South Africa

In South Africa, the need for additional water supplies has instigated substantial research into water reclamation. The only known operation reclaiming sewage directly for potable use on a permanent basis was put on stream in Windhoek, South West Africa, during the late 1960's. The design capacity of the Windhoek plant is 1.17 mgd and during the first two years of operation, the reclamation plant has contributed an average of 13.4 percent of the total local water consumption.

Figure No. 35 on the following page, schematically illustrates the plant processes. Following conventional secondary treatment by trickling filtration and maturation (oxidation) ponding, the water is sent through a tertiary plant consisting of the following unit processes:

- pH correction with carbon dioxide
- Algae flotation (aided by alum sulphate)
- Foam fractionation
- Lime flocculation
- Breakpoint chlorination
- Sedimentation
- Rapid sand filtration
- Activated carbon adsorption
- Post chlorination

A key element in the process chain is the stimulation of algae growth in the maturation ponds in order to remove nutrients. The maturation pond effluent is then subjected to extensive treatment to remove algae, settleables, and suspended solids. Referring to Figure 35, it is seen that breakpoint chlorination is practiced to provide a free chlorine residual through the sand filters and oxidize ammonia-nitrogen. Carbon adsorption and final chlorination to a free chlorine residual of 0.5 mg/l completes the treatment process. Two chlorine residual recorders with alarm actuators ensure proper chlorination.

The typical plant effluent quality attained from the Windhoek facility is shown in Table 40. A comparison with the WHO limits previously shown in Table 39, shows that Windhoek exceeds the "acceptable" values for color, TDS, COD, and ABS; however, stays well under the "allowable" limits. Subsequent blending of the effluent into the normal potable supply from Goreangab Dam improves all quality parameters of the combined water to better than the WHO "acceptable" values. Average percentage of reused water in the combined water is 13 percent with a reported range of 0 to 28 percent.

Problems experienced at the Windhoek plant include the following:

- Mechanical failures in the algae flotation and foam fractionation units (now corrected)
- Tertiary plant shutdown for activated carbon regeneration

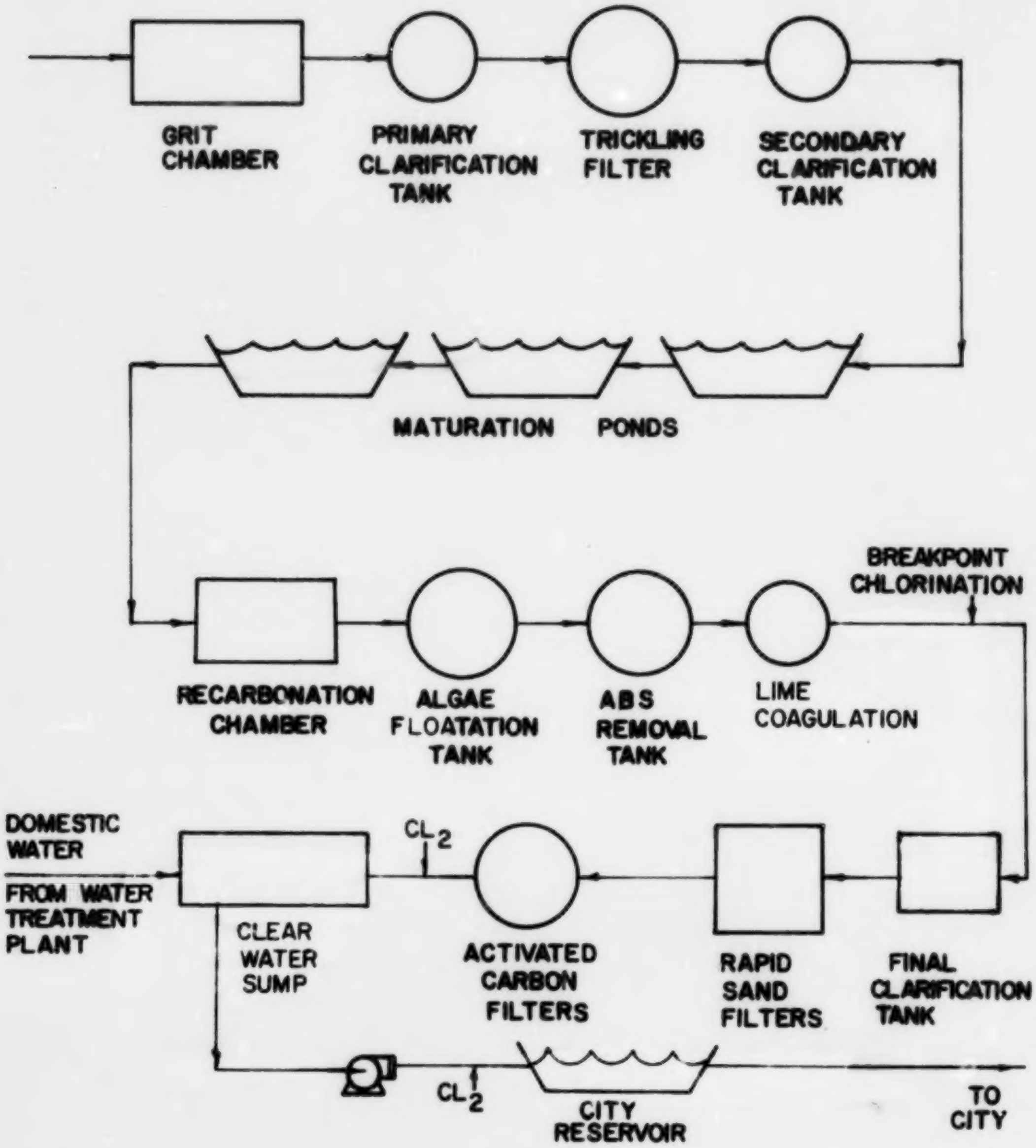
GRIT CHAMBER
PRIMARY CLARIFICATION TANK
TRICKLING FILTER
SECONDARY CLARIFICATION TANK
MATURATION PONDS
BREAKPOINT CHLORINATION
RECARBONATION CHAMBER
ALGAE FLOATATION TANK
ABS REMOVAL TANK
LIME COAGULATION
DOMESTIC WATER
FROM WATER TREATMENT PLANT
CL_2
CLEAR WATER SUMP
ACTIVATED CARBON FILTERS
RAPID SAND FILTERS
FINAL CLARIFICATION TANK
CL_2
CITY RESERVOIR
TO CITY

FIGURE 35
GAMMAMS SEWAGE PURIFICATION WORKS
WINDHOEK, SOUTH WEST AFRICA

Table 40. TYPICAL QUALITY OF EFFLUENTS FROM WINDHOEK AND GRAND CANYON

Parameter, mg/l	Facility	
	Windhoek	Grand Canyon
pH	7.8	6.9-7.2
Color	8	-
Turbidity	4	-
TDS	540	616
Sulfates	125	-
Chlorides	62	200
Nitrates	9	-
Ammonium Nitrogen	0.2	-
Kjeldahl Nitrogen	0.5	-
COD	14	-
BOD	0.3	5-10
DO	-	-
ABS	0.7	-
Coliforms	0	0
Sodium	76	-
Potassium	19	-
Phosphates	0.016	-

- Excessive maturation pond ammonia levels during winter months, making treatment to reuse levels uneconomical

As a result of these problems, the plant has operated at only 50 percent of design capacity.

The plant also experiences substantial water losses in the algae flotation and foam fractionation units and backwash of sand and activated carbon filtration systems. These losses account for over 10 percent of the plant influent volume.

The Windhoek water reclamation plant operated from October 1968 until the end of 1970. Towards the beginning of 1971, the loading on the conventional sewage treatment works had increased to such an extent that the quality of the maturation pond effluent did not comply with the water quality specifications of the reclamation plant. Reclamation of treated sewage effluent was therefore stopped temporarily pending upgrading of the conventional sewage treatment facilities. In addition, increased rainfall in the area eliminated the urgent need for water reclamation. The plant will be commissioned again upon expansion of the conventional treatment works.

All information on the Windhoek plant presented in the foregoing section was derived from the technical literature.(2,3,7,8,9)

Grand Canyon Village, Arizona

The Grand Canyon, Arizona, wastewater treatment facility, operated by the National Park Service, provides water for direct, non-potable domestic uses. (A field investigation is included in Appendix A of this report). During the May through September high-use season an average of 30,000 gpd of reclaimed water (approximately 7 percent of the total water demand during the period) is used for: toilet flushing, car washing, irrigation, construction, and stock watering. All water use decreases significantly during the winter months.

The largest single use of the effluent is for flushing public toilets in the older lodges, motels, dorms, and cafeterias within the village. Irrigation of the high school football field and landscaping is another major use of reclaimed water, and minor quantities are used for vehicle washing and road construction.

Treatment consists of conventional activated sludge followed by anthracite filtration and final chlorination to a high 5 mg/l residual. Typical effluent characteristics were shown in Table 40.

The Grand Canyon plant is non-automated. Chlorine residual is considered to be the most critical parameter and is checked every 24 hours by plant personnel. Specific effluent quality limits are as follows:

10 mg/l BOD
10 mg/l SS
200 per 100 ml coliforms, MPN

The effluent is reported to be substandard in quality approximately two percent of the time.

Pikes Peak

A potential domestic reuse system has been partially evaluated at Pikes Peak, Colorado. Toilet and kitchen wastes generated at this recreation area will be treated to allow reuse on site for toilet flushing. To date only the treatment system has been evaluated. Acceptability of the effluent cannot be fully evaluated until the U.S. Forest Service selects a permanent location for the installation on the Peak site. Treatment is conducted in a closed activated sludge-ultrafiltration unit of proprietary design. The ultrafiltration portion acts as a positive barrier to the movement of biomass out of the system. Thus, the system can operate at a very long SRT which is conducive to high treatment efficiency. In addition, the ultrafiltration membrane prevents escape of high molecular weight soluble organics and colloidal matter.

At Pike's Peak, 15,000 gpd have been produced by this process. Typical quality values reported for August-September 1970 are summarized in Table 41 below.

Table 41. SUMMARY OF PERFORMANCE OF THE DORR-OLIVER ACTIVATED SLUDGE-ULTRAFILTRATION PLANT OPERATIONS AT PIKES PEAK AUGUST-SEPTEMBER 1970

	Influent mg/l	Effluent mg/l	Percent Removal
BOD	285	1	99
COD	547	32	94
TOC	136	6.6	95
Turbidity (JTU)	47	0.33	-
Color (units)	320	40	-
TSS	129	-	100
MLSS	3,954	-	-
Coliform (per 100 ML)	-	-	100
PO_4-P	9.1	11.1	-
pH	7.9	5.9	-
Threshold Odor Number	-	6	-

Average Flux 11.0 GFP = 21,000 GPD

ANALYSIS OF CURRENT ECONOMICS

Windhoek is reported to produce effluent at $577/MG, including amortized capital costs. Table 42 on the following page summarizes the tertiary treatment costs over the first two years of operation.

These costs do not include that of conventional sewage treatment and are based on the actual plant flow at roughly 50 percent of design. For the maximum 80 percent utilization, the total unit cost would drop to $495/MG; a figure which compares favorably with the unit cost of $530/MG for conventional water treatment of surface water supplies at Windhoek.

The combination of tertiary unit processes at Windhoek proved to be an economical system for production of

Table 42. TERTIARY TREATMENT COSTS AT WINDHOEK, SOUTH AFRICA (1968-1970)(9)

Cost Item	$/MG
Capital costs	194
Labor	44
Chemicals	144
Activated carbon	120
Specialized supervision	75
Total	$577

reclaimed water. A constraint is imposed upon the cost evaluation, however, by the previously discussed inability of the sewage treatment facility to always provide an effluent suitable for reclamation by the tertiary treatment processes.

The cost of treatment at Grand Canyon is estimated at $604/MG not including capital amortization, and $2,580/MG including capital amortization. The high cost of the Grand Canyon effluent is due to its' low volume, and is not indicative of "normal" cost for non-potable domestic reuse.

It is not known what revenues, if any, are received by the city of Windhoek for reused water. Grand Canyon, however, has a specific rate structure for its water. The charge for renovated water is $1,750/MG except where fresh potable water is available. If fresh water is available, the charge is $1,000/MG to provide stronger incentive for reuse since fresh water is priced at $2,450/MG. The importance of the reclaimed water supply is emphasized by the method of fresh water transport. Fresh water is piped 15 miles across the Grand Canyon and pumped 3,400 feet vertically. The National Park Service realized $11,000 on sales of renovated water in 1971.

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SECTION VI

FISH PROPAGATION AND FARMING

INTRODUCTION

Current programs involving the propagation of fish in treated municipal wastewater lagoons provide encouragement that this type of water reuse has good potential. Two major potential applications are: (1) recreational fishing, and (2) commercial fish farming.

Although various species of fish exist in numerous municipal wastewater treatment lagoons, stocking of effluent lakes and ponds for public recreational fishing is done in relatively few locations in the county. As treatment processes become more advanced and effluent qualities improve, however, the use of effluent lakes and ponds for raising recreational fish may become more popular.

We were unable to locate any current commercial fish farming operations utilizing reclaimed sewage in the United States. Several foreign countries, notably Israel, as well as several countries in Asia and Europe have practiced pisciculture in wastewater lagoons. The studies and pilot programs referenced in this chapter generally indicate a cautious optimism toward the feasibility of wastewater fish farming.

Required Quality Criteria

Of primary importance in fish farming is the presence of dissolved oxygen in sufficient concentrations to support fish life.

When wastewater is the environment, the potentially significant BOD concentration is particularly critical since it can reduce or totally deplete oxygen levels in the water.(1)

Ammonia is a detrimental constituent common to wastewater; even very low concentrations can result in significant fish kills.(3) The toxicity of ammonia and ammonium salts to fish is directly related to the amount of undissociated ammonium hydroxide in the water which in turn is a function of pH according to the following equilibrium equation:(2)

$$\frac{[NH_4^+][OH^-]}{[NH_4OH]} = 1.8 \times 10^{-5}$$

As the pH is raised the concentration of unionized ammonia and toxicity increases. One researcher found that the toxicity of a given concentration of ammonium compounds toward fish increased by 200 percent between pH 7.4 and 8.0.(2)

Other sources documented in Reference 2, show that the toxicity of ammonia to fish is increased markedly at low-concentrations of dissolved oxygen. One theory explains that at low DO levels, the concentration of fish excreted CO_2 is reduced and thus, the pH value of the water in contact with the gill surface rises, leading to increased toxicity of ammonium hydroxide as explained above.

Of equal importance to water quality is the presence of pathogenic bacteria and viruses, certain heavy metals (such as mercury), and pesticides and herbicides. Their presence in the reclaimed water could be hazardous to both the fish and the individuals who eat the fish.(4) Tables 43 and 44 offer typical limiting concentrations of selected quality parameters.

ANALYSIS OF CURRENT PROCESS PRACTICES

As summarized in Tables 45 and 46 current practices in the United States for raising of fish in wastewater lagoons is limited to recreational fishing operations. Pilot experiments with fish farming in treated sewage effluent have been conducted in Michigan and Las Virgenes, California. Appendix A provides a field investigation of the Las Virgenes operation, including specifics on their fish farming experimentation. Overseas, successful fish farming is reported in Israel.

Quality of effluent is of paramount importance to a healthy fish population. Conventional secondary treatment is unable to sufficiently remove some pollutants that could be toxic fish life, e.g., some pesticides and algacides, heavy metals, and some components of industrial wastes. Table 47 shows the low percentage of industrial waste in the influent of municipal plants providing treated wastewater for raising fish.

Table 48 summarizes the water quality characteristics of the reservoirs holding fish. In the case of Lancaster, Santee, and Indian Creek, these reservoirs are recreational lakes

Table 43. TENTATIVE GUIDES FOR THE QUALITY OF WATER REQUIRED FOR FISH LIFE(1)

Determination	Threshold concentration*
	Fresh water
Total dissolved solids (TDS), mg/liter	2,000#
Electrical conductivity, µmhos/cm @ 25°C	3,000#
Temperature, maximum °C	34
Maximum for salmonoid fish	23
Range of pH	6.5-8.5
Dissolved oxygen (D.O.), minimum mg/liter	5.0+
Flotable oil and grease, mg/liter	0
Emulsified oil and grease, mg/liter	10#
Detergent, ABS, mg/liter	2.0
Ammonia (free), mg/liter	0.5#
Arsenic, mg/liter	1.0#
Barium, mg/liter	5.0#
Cadmium, mg/liter	0.01#
Carbon dixoide (free), mg/liter	1.0
Chlorine (free), mg/liter	0.02
Chromium, hexavalent, mg/liter	0.05#
Copper, mg/liter	0.02#
Cyanide, mg/liter	0.02#
Fluoride, mg/liter	1.5#
Lead, mg/liter	0.1#
Mercury, mg/liter	0.01
Nickel, mg/liter	0.05#
Phenolic compounds, as phenol, mg/liter	1.0
Silver, mg/liter	0.01
Sulfide, dissolved, mg/liter	0.5#
Zinc, mg/liter	0.1

*Threshold concentration is value that normally might not be deleterious to fish life. Waters that do not exceed these values should be suitable habitats for mixed fauna and flora.

#Values not to be exceeded more than 20 percent of any 20 consecutive samples, nor in any 3 consecutive samples. Other values should never be exceeded. Frequency of sampling should be specified.

+Dissolved oxygen concentrations should not fall below 5.0 mg/liter more than 20 percent of the time and never below 2.0 mg/liter. (Note: Recent data indicate also that rate of change of oxygen tension is an important factor, and that diurnal changes in D.O. may, in sewage-polluted water, render the value of 5.0 of questionable merit.)

Table 44. APPROXIMATE LETHAL CONCENTRATIONS OF SELECTED CHEMICALS TO FISH LIFE(1)*

CHEMICAL	ORGANISM TESTED	LETHAL CONCENTRATION, mg/LITER
ABS (100 percent)	Fathead minnow	3.5-4.5
ABS (100 percent)	Bluegills	4.2-4.4
Household syndets	Fathead minnow	39-61
Alkyl sulfate	Fathead minnow	5.1-5.9
LAS (C12)	Bluegill fingerlings	3
LAS (C14)	Bluegill fingerlings	0.6
Acetic acid	Goldfish	423
Alum	Goldfish	100
Ammonia	Goldfish	2-2.5 NH_3
Ammonia	Perch, roach, rainbow trout	3 N
Sodium arsenite	Minnow	17.8 As
Sodium arsenate	Minnow	234 As
Barium chloride	Goldfish	5000
Barium chloride	Salmon	158
Cadmium chloride	Goldfish	0.017
Cadmium nitrate	Goldfish	0.3 Cd
CO_2	Various species	100-200
CO	Various species	1.5
Chloramine	Brown trout fry	0.06
Chlorine	Rainbow trout	0.03-0.08
Chromic acid	Goldfish	200
Copper sulfate	Stickleback	0.03 Cu
Copper nitrate	Stickleback	0.02 Cu
Cyanogen chloride	Goldfish	1
H_2S	Goldfish	10
HCI	Stickleback	pH 4.8
HCI	Goldfish	pH 4.0
Lead nitrate	Minnow, stickleback, brown trout	0.33 Pb
Mercuric chloride	Stickleback	0.01 Hg
Nickel nitrate	Stickleback	1 Ni
Nitric acid	Minnow	pH 5.0
Oxygen	Rainbow trout	3 cc/liter
Phenol	Rainbow trout	6
Phenol	Perch	9
Potassium chromate	Rainbow trout	75
Potassium cyanide	Rainbow trout	0.13 Cn
Sodium cyanide	Stickleback	1.04 Cn

Table 44.(Continued)

CHEMICAL	ORGANISM TESTED	LETHAL CONCENTRATION, mg/LITER
Silver nitrate	Stickleback	70 K
Sodium fluoride	Goldfish	1000
Sodium sulfide	Brown trout	15
Zinc sulfate	Stickleback	0.3 Zn
Zinc sulfate	Rainbow trout	0.5
Pesticides		
1. Chlorinated hydrocarbons		
Aldrin	Goldfish	0.028
DDT	Goldfish	0.027
DDT	Rainbow trout	0.5-0.32
DDT	Salmon	0.08
DDT	Brook trout	0.032
DDT	Minnow, guppy	0.75 ppb
DDT	Stoneflies (species)	0.32-1.8
BHC	Goldfish	2.3
BHC	Rainbow trout	3
Chlordane	Goldfish	0.082
Chlordane	Rainbow trout	0.5
Dieldrin	Goldfish	0.037
Dieldrin	Bluegill	0.008
Dieldrin	Rainbow trout	0.05
Endrin	Goldfish	0.0019
Endrin	Carp	0.14
Endrin	Fathead minnow	0.001
Endrin	Various species	0.03-0.05 ppb
Endrin	Stoneflies (species)	0.32-2.4 ppb
Heptachlor	Rainbow trout	0.25
Heptachlor	Goldfish	0.23
Heptachlor	Bluegill	0.019
Heptachlor	Redear sunfish	0.017
Methoxychlor	Rainbow trout	0.05
Methoxychlor	Goldfish	0.056
Toxaphene	Rainbow trout	0.05
Toxaphene	Goldfish	0.0056
Toxaphene	Carp	0.1
Toxaphene	Goldfish	0.2
Toxaphene	Goldfish	0.04
Toxaphene	Minnows	0.2

Table 44.(Continued)

CHEMICAL	ORGANISM TESTED	LETHAL CONCENTRATION, mg/LITER
2. Organic phosphates		
Chlorothion	Fathead minnow	3.2
Dipterex	Fathead minnow	180
EPN	Fathead minnow	0.2
Guthion	Fathead minnow	0.093
Guthion	Bluegill	0.005
Malathion	Fathead minnow	12.5
Parathion	Fathead minnow	1.4-2.7
TEPP	Fathead minnow	1.7
3. Herbicides		
Weedex	Young reach	40-80
Weeda Zol	and	15-30
Weeda Zol T.L.	trench	20-40
Simazine (no plants present)	Minnow	0.5
Atrazine (A361) (plants present)	Minnow	5.0
Atrazine in Gesaprime	Minnow	3.75
4. Bactericides		
Algibiol		
Soricide	Minnow	20
tetraminol	Minnow	8

*Note: This table is a summary derived from numerous sources as specifically listed in reference (1).

Table 45. INVENTORY OF REUSE OPERATIONS FOR RECREATIONAL FISHING IN THE UNITED STATES

MUNICIPAL PLANT LOCATION	FISH SPECIES RAISED	REUSE VOLUME (mgd)	LEVEL OF MUNICIPAL TREATMENT
Los Angeles, CA (L.A. County Sanitation Districts, Lancaster Plant)	Bass Channel Catfish Gambusia Redeared Sunfish Trout	0.5	Tertiary
Santee, CA	Bluegill Channel Catfish Gambusia Largemouth Bass Rainbow Trout Redeared Sunfish Threadfin Shad	1.0	Secondary
South Lake Tahoe, CA (South Tahoe PUD)	Rainbow Trout	2.7	Tertiary
Colorado Springs, CO (U.S. Air Force Academy)	Smallmouth Bass Trout	1.4	Tertiary
Okolona, KY (Okolona Sewer Const. Dist.)	Bluegill Largemouth Bass Minnows	1.0	Secondary

Table 46. INVENTORY OF FISH FARMING PILOT STUDY OPERATIONS IN THE UNITED STATES

MUNICIPAL PLANT LOCATION	FISH SPECIES RAISED	TYPE OF MUNICIPAL TREATMENT
Bangor, Mich.	Fathead Minnows	Oxidation Pond
Belding, Mich.	Fathead Minnows	Oxidation Pond
Carson City, Mich.	Golden Shiners Muskies	Oxidation Pond
Coopersville, Mich.	Bottom Muds Fathead Minnows Golden Shiners Tiger Muskies	Oxidation Pond
Eau Claire, Mich.	Fathead Minnows	Oxidation Pond
Gassopolis, Mich.	Fathead Minnows	Oxidation Pond
Lawton, Mich.	Fathead Minnows	Oxidation Pond
Las Virgenes, Ca.	Fathead Minnows Gambusia Bass Catfish Crappie Bluegill	High Quality Activated Sludge

Table 47. PRESENCE OF INDUSTRIAL WASTE IN MUNICIPAL PLANT INFLUENT

Plant	Average Flow (MG)	Percent of Industrial Waste in Influent
Lancaster, California	4.0	5
Santee, California	3.3	1
Okolona, Kentucky	1.0	0.1
Colorado Springs, Colorado	1.5	0
Indian Creek, California	2.7	0
Michigan (total of 7 plants)	10.0	5

fed from effluent from tertiary wastewater treatment. The fish in Okolona, Kentucky are raised in aerated lagoons and those in Michigan in oxidation ponds at the treatment plants.

Table 48. BASIC WATER QUALITY CHARACTERISTICS OF RECLAIMED WATER RESERVOIRS FOR FISH PROPOGATION(2)

	BOD mg/l	SS mg/l	pH	Cl^1 mg/l	Coliform MPN	TDS mg/l
Lancaster, Calif.	1.4-2.2	28-32	7.7-8.6	--	2.2	843-942
Santee, Calif.	-	-	8.8	270-480	<2.2	1150-1600
Indian Creek, Calif.	6.6	3.4	8.3-8.4	22	-	120-416
Okolona, Michigan			Not Known			
Belding, Michigan(1)	2-10	5-10	7.3-7.6	100-150	-	-

(1) One of 7 similar treatment facilities in Michigan that participated in pilot fish farming programs.

(2) See Chapter IV "Recreation" for extensive quality characteristics for the Lancaster, Santee, and Indian Creek operations.

Controversy exists regarding the necessary degree of treatment to provide an optimum wastewater lagoon habitat for fish. There is an apparent trade-off between water quality and availability of natural food for the food chain. Primary treatment removes most of the settleable solids but leaves a larger percentage of the nutrients and BOD to provide food for the aquatic food chain. However, water quality is usually poor and DO levels often approach the threshold values of fish survival. Secondary treatment prior to release to fish inhabited lagoons provides advantages of much improved water quality (higher DO, lower BOD, COD, SS) but removes a portion of the nutrients available to stimulate growth of aquatic plants. Tertiary treatment provides the highest water quality but is capable of removing nearly all nutrient value.

As of yet, standard measurements have not been made of several important water characteristics affecting fish. Although much research has been conducted regarding lethal limits and observable deleterious effects of various concentrations of pollutants, little has been done to investigate water characteristics that taint the flesh or impart tastes and odors to the fish. These considerations are of importance if commercial fish farming in reclaimed wastewater is to be successful in this country.

From the inventory of existing operations in Appendix B it can be seen that four out of the five recreational fishing systems employ some type of tertiary treatment. The Air Force Academy plant has two oxidation ponds, following trickling filters, prior to discharge to the fishing lakes. Santee, California takes advantage of a natural sand bed, for its tertiary treatment. After secondary treatment the wastewater percolates through a 15 ft depth of sand and soil in a spreading area consisting of 6 basins of about 1/2 acre each. The water then flows horizontally through the sand-soil strata for approximately 400-1,500 feet into the first of a series of recreational lakes.

Lancaster, California employs a tertiary treatment system following secondary oxidation ponds. It consists of: chemical coagulation, sedimentation, multi-media filtration (anthrafilt, sand, gravel), and chlorination. Indian Creek Reservoir is fed with waters from the much publicized Lake Tahoe water reclamation plant. Tertiary treatment at Lake Tahoe is comprised of: chemical coagulation, sedimentation, ammonia stripping, 2-stage recarbonation, mixed media filtration, granular carbon adsorption and chlorination. The remaining recreational facility, Okolona, Kentucky, has plans for future expansion to more advanced aerated lagoon treatment but currently involves only two lagoons in series, the second one being aerated with a Hinde system and containing the fish.

In comparison, the pilot fish farming study by the Michigan Department of Natural Resources, Fishery Division, was conducted at municipal plants with only settling preceding the lagoons. The program in Michigan and at Okolona, Kentucky were not extensively monitored as to water quality and its affect on the fish population.

Naturally, the species of fish best suited for stocking in wastewater lakes and lagoons is directly contingent upon water quality. Species that are more tolerant of most common pollutants include minnows, gambusia, catfish, carp, muskies, bluegill, and small mouth bass which have better chances of survival in effluent from primary treatment. As water quality improves and stabilizes with secondary and tertiary treatment, less tolerant, higher quality fish such as brown and rainbow trout can survive successfully.

Most waste treatment operations will occasionally have problems and plants upsets. These may become critical if a lagoon or lake containing fish receives the treated effluent. Specific problems were mentioned by five of the six operations covered in this chapter (Okolona, Kentucky reported no problems).

At the Air Force Academy, a transfer of low DO water from an upstream oxidation pond caused a fish kill in one of their recreation lakes. Concern is also indicated that concentrations of copper in bottom muds, from now discontinued applications of $CuSO_4$ algacide, will re-enter the water and build up in the aquatic food chain. This is being closely monitored. Details of the recreational fishing program, wastewater treatment, and water qualities at the Air Force Academy are supplied in a case study report in Appendix A.

Lancaster, California reports problems with high NH_3 levels during winter months which could be critical because of ammonia's high toxicity to fish. Build up of heavy metals in the fish population at Lancaster is being monitored and a report to EPA is being prepared. Appendix A contains an in-depth discussion of Lancaster reuse systems.

Santee, California's greatest concern is meeting the stringent TDS discharge requirement established by the Regional Water Quality Control Administration (400 mg/l increase in concentration above those concentrations in the public water supply). Santee also experienced an unusual fish kill which was believed to have been caused by a bloom of algae (statoblasts) concentrations. Several similar cases known as "red tides" have been reported on the eastern coast of Florida and in California.

The only water quality problem experienced at Indian Creek reservoir occured during the winter of 1971 prior to ammonia stripping operations at the Lake Tahoe treatment plant. An

8 inch ice cover on the reservoir melted very rapidly releasing a surge of nutrients and NH_3 into the water. Concurrently, loss of the ice cover allowed escape of CO_2 from the lake water which raised the pH and increased the toxicity of the ammonia concentrations. Approximately 5% to 10% of the fish in the reservoir were killed during this incident. However, no similar problems have occurred since, and the treatment plant now operates an ammonia stripping unit to safeguard against such occurances in the future.

The fish farming operation in Michigan experienced winter kills in nearly all of their lagoons.(4) Ice cover shut out light and eliminated surface aeration while plant respiration and organic matter decay continued, thus greatly reducing the DO concentration in the water and killing the fish. Also of concern in the Michigan study was the buildup of mercury in the fish of one of ponds coupled with the knowledge that toxic industrial wastes could not be diverted once they had reached the treatment plant. The most critical problem indicated in the Michigan study(4) was the potential health hazard of transfer of human pathogens from the sewage effluent to the fish and back to man. The unanswered health questions were the basis of their decision to terminate their experimental operation until conclusive information could be developed.

ANALYSIS OF CURRENT ECONOMICS

The economics of current recreational fishing operations in treated wastewater lagoons and lakes are difficult to analyze. Costs associated with the treatment operations themselves are given in Table 49. In most of these operations, fish are simply an added benefit and recreational fishing was not a significant factor in determining type or cost of treatment. The recreational benefits to the public are real, but beyond the scope of this study to evaluate. One general recreational benefit-cost analysis is provided in the case study report on Lancaster, California in Appendix A.

If these reclaimed water recreation operations are compared with small commercial fishing lakes, it can be assumed that each fisherman could be assessed a fee of $1.00 per day for use of the facility. Currently, none of the programs charge patrons to fish on their lakes. However, authorities at Lancaster anticipate a facility fishing permit of $1 per fisherman per day to help finance the extensive stocking program.

Commercial fish farming in wastewater treatment plant effluent is governed by economics. The pilot fish farming operation by the Natural Resources Department of the State of

Michigan showed that certain species of fish could grow and reproduce successfully in primary sewage and that possible economic gain may be realized as well. Approximately 400-800 lbs/acre of fathead minnows were raised at the Belding, Michigan Wastewater Treatment plant in 1971. The minnows were harvested and transported to a nearby state fish hatchery at a total cost of $0.15/lb. The normal price paid by the state for forage minnows from commercial hatcheries is $0.50/lb. The basic areas for savings over normal hatchery operations are: (1) reduction of artificial feeding (dependent on degree of treatment with more advanced treatment removing greater quantities of natural food); and (2) lower water costs.

Table 49. TREATMENT COSTS FOR REUSE FOR RECREATIONAL FISHING*

Municipal Plant Code	Treatment Cost ($/MG) Incl. Capital Amort.	Treatment Cost ($/MG) Excl. Capital Amort.
CA-39	130	44
CA-63	520	268
CA-65	1,747	1,086
CO-3	498	126
KY-1	211	134

*See Appendix E for calculation procedure.

SPECIFIC REFERENCE BIBLIOGRAPHY FOR CHAPTER VI

1. McGauhey, P.H., Engineering Management of Water Quality, McGraw-Hill, New York, 1968.

2. McKee, J.E., and Wolf, H.W., Water Quality Criteria, California State Water Resources Control Board, Publication No. 3-A, 1963.

3. Personal communication, February 27, 1973, Robert C. Summerfelt, PhD., Oklahoma State University, Department of Zoology.

4. Personal communication, January 31, 1973, John D. Schrouder, State of Michigan, Department of Natural Resources, Fisheries Division.

SECTION VII

SUMMARY

This report provides the results of the effort performed by SCS Engineers under Contract 68-03-0148 to the U.S. Environmental Protection Agency, National Environmental Research Center-Cincinnati, Ohio. The project compiled an updated listing of municipal wastewater reuse operations, and utilized questionnaires and field visits to obtain information describing current treatment and reuse practices. Municipalities contemplating various kinds of wastewater reuse will find the report useful in identifying existing operations elsewhere which have initiated similar reuse practices. For most reuse operations (very small irrigation operations excluded) data is provided pertinent to volume, effluent quality, municipal treatment, user treatment, costs, specific reuse, quality safeguards, and other information. Report data is provided in English units. Appendix F is provided for those who wish to convert English units into metric.

The types of reuse covered in this study are:

- Irrigation and other agricultural uses
- Cooling water
- Industrial process water
- Boiler feed water
- Recreational lakes
- Fish propagation
- Non-potable domestic use

Separate chapters were prepared describing the results of the study by category of reuse; i.e., irrigation, industrial, recreation, fish propagation, and domestic. Each chapter contains sections covering water quality criteria for the specific reuse, a listing and analysis of existing operations supplying wastewater for the specific reuse, and an economic analysis.

As shown in Figure 36, of the above types of reuse by far the greatest number of plants practice reuse by irrigation. In terms of volume, however, irrigation reuse accounts for only slightly more than half the reuse reported, with industrial reuse a close second. Figure 37 shows the comparative volumes by types of reuse. One large industrial reuser, the Bethlehem Steel Corp. in Baltimore, Maryland (170 mgd) significantly effects the volume comparison.

Geographically the reuse operations are concentrated in the semi-arid Southwestern United States. As shown in Table 50, Texas with 149 municipal reuse operations and California with 138 are far ahead of other states.

Irrigation Reuse

The irrigation chapter provides an excellent tabulation (Table 10) by crop of the municipalities that are supplying effluent for irrigation of that crop. Thirty-nine types of irrigation reuse are represented, ranging from golf courses (30 locations) to sugar beets (3 locations). A subsequent tabulation (Table 14) summarizes the quality of effluent being applied to various crops. A wide quality range is represented, e.g., BOD of 15 to 370 mg/l for cotton, showing that the effluent quality ranges from poor primary to excellent secondary. Of particular interest are the

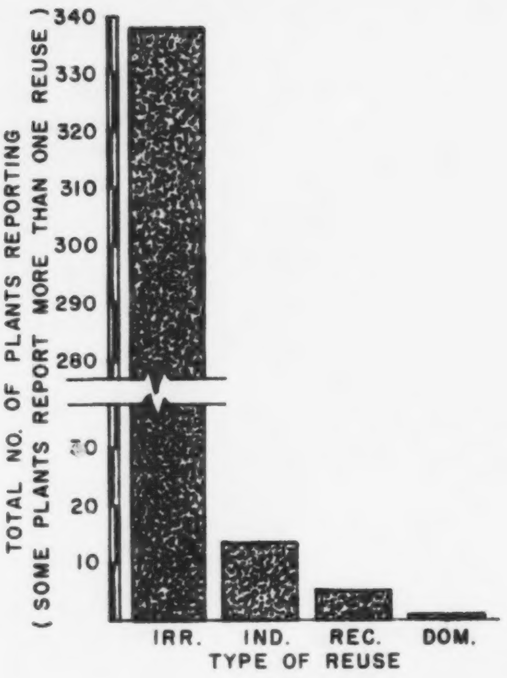

FIGURE 36

RENOVATED WATER USES

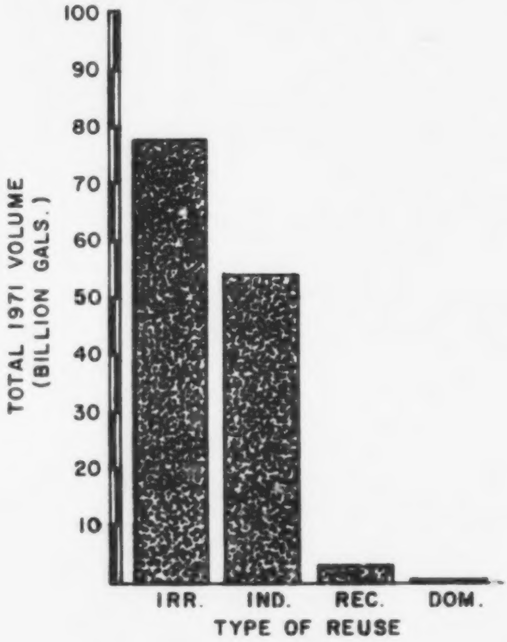

FIGURE 37

RELATIVE REUSE VOLUMES IN THE UNITED STATES

Table 50. GEOGRAPHICAL DISTRIBUTION OF REPORTED MUNICIPAL REUSE

State	No. of Municipalities Practicing Reuse				
	Irr.	Ind.	Rec.	Dom.	Total
Texas	144(2)	5	0	0	149
California	134(1)	1	3	0	138
Arizona	28(3)	2	0	1	31
New Mexico	10	0	0	0	10
Colorado	5	1	1	0	7
Nevada	4	2	0	0	6
Michigan	1	1	0	0	2
Florida	2	0	0	0	2
Oklahoma	1	1	0	0	2
Washington	2	0	0	0	2
Missouri	2	0	0	0	2
Maryland	0	1	0	0	1
Kentucky	0	0	1	0	1
North Dakota	1	0	0	0	1
Indiana	1	0	0	0	1
Nebraska	1	0	0	0	1
Oregon	1	0	0	0	1
Utah	1	0	0	0	1
Totals	338	14	5	1	358

(1) Includes 61 very small irrigation disposal which are not included in comprehensive data tabulation, Appendix B.

(2) Includes 135 very small irrigation disposal which are not included in comprehensive data tabulation, Appendix B.

(3) Includes 13 very small irrigation disposal which are not included in comprehensive data tabulation.

high average TDS (over 800 mg/l) and Na (over 300 mg/l) levels of reclaimed waters used for irrigation. These average values indicate that relatively poor waters in terms of dissolved salts are being successfully used on a wide variety of crops, with proper irrigation management.

The prevalent relationship between the municipal suppliers of effluent and the users of the effluent for irrigation is to suit the crop to the quality of the effluent. If contaminants are present which are not readily removed by conventional treatment, e.g., TDS and Boron, crops are selected which tolerate the contaminant. In most cases, irrigation reuse is more a method of disposal than an alternative to fresh water supplies.

Of the plants returning questionnaires, approximately 25 percent of those furnishing effluent for irrigation provide only the equivalent of primary treatment (see Table 13). The majority are small plants which irrigate small acreages of pasture, landscape or animal feed crops. One large user of primary effluent for irrigation is located at Bakersfield, California and is described in the field investigation reports (Appendix A). As a result of developing concern over the potential long-term damage to groundwater and soil from use of primary effluent, it is probable that regulatory agencies will eventually require secondary treatment of effluent for irrigation at Bakersfield and elsewhere.

Few of the reuse applications are irrigation of crops for human consumption. Most of the crops for human consumption are those that do not come into direct contact with effluent such as grapes, citrus, and other tree crops. Truck crops such as asparagus, beans, cucumbers, onions, spinach, and tomatoes are irrigated at least partially with effluent only at three California sites; Camarillo, Irvine, and Livermore; and at two Washington sites; Walla Walla, and Warden. The Walla Walla operation is described in the field investigation reports (Appendix A).

Only 18 of the irrigation reuse operations reported no effluent storage available, and most have storage of two days or more. Comments received from operators, irrigators, and regulatory agencies emphasized the importance of substantial storage facilities for effluent and tail water in order to balance irrigation demands, allow for rainy periods when the fields are saturated, and prevent run-off. Approximately half the operations reported having alternate sources of irrigation water in addition to the municipal effluent.

The study acquired a great deal of information pertinent to economics of reuse by irrigation and other means. This is summarized and presented at end of each specific reuse chapter. In a report involving data from many plants, there is danger of overuse of the data obtained to arrive at broad conclusions which are meaningless for a specific reuse application. This is true particularly of the economics of sewage treatment and reuse which are subject to many factors completely outside the scope of this study. The reader is urged, therefore, to make a detailed investigation, before applying economic data presented herein to another location where conditions are only superficially similar.

Only 25 municipal producers of irrigation water report they sell their renovated product. Most municipalities look upon the irrigation operations as primarily a means of disposal, and are not prone to demanding payment for effluent which they would otherwise waste. In some cases the irrigation operation allows the municipality to provide only primary treatment, whereas if discharge were made to surface waters a high degree of secondary treatment would be necessary. Municipal revenues from irrigation are estimated to equal less than one percent of the treatment cost incurred by the municipality. As a whole, municipalities are apparently not demanding sufficient revenue for reclaimed wastewater they supply for irrigation.

Among those municipalities charging for their effluent, it appears that charges for effluent are primarily influenced by factors other than effluent quality. Among these factors are fresh water cost and availability in the area, prior water rights in the area, and the municipality's failure to recognize its effluent as a valuable commodity rather than something to be discarded.

Industrial Reuse

Only 15 industrial plants are presently reusing municipal wastewater in the United States, including three city-owned power plants, so private industry is represented by only 12 plants. Obviously, numerous potential reuse opportunities remain unrecognized.

Cooling (154 mgd), boiler feed (1 mgd) and copper mining (1 mgd) are the three reported uses for treated municipal effluent. Obviously, cooling is predominant, and excellent examples of successful operations are described in Appendix A of this report for Burbank, California; Las Vegas, Nevada; Baltimore, Maryland; and five sites in Texas.

Cooling water technology is complex, and the use of reclaimed sewage presents special problems of treatment and control to responsible operating personnel. The difference between treated sewage effluent and fresh water must be recognized and planned for, or serious problems will occur in the heat exchange and cooling system.

The Bethlehem Steel Company cooling system which uses Baltimore, Maryland municipal effluent is a once through system, and successfully uses a relatively poor quality secondary effluent. The other industrial reusers use the effluent in recirculating cooling systems and require a much higher quality water supply. Chapter III, Industrial Reuse, provided several tabulations (Tables 21 and 29) detailing water quality necessary, and the field investigation reports (see Appendix A) for Lubbock, Texas (see Table A-29), and Odessa, Texas (see Table A-31) describe water quality criteria at those locations. Generally, the industrial reuser treats the municipal effluent with lime clarification prior to use in order to reduce phosphates, organics, and suspended solids. After lime treatment, the reclaimed water is more heavily chlorinated and acid treated than is customary for fresh water supplies. Burbank, California is unusual because the power plant there does not find it necessary to lime treat the municipal effluent prior to use. The Burbank sewage treatment plant, however, produces an outstanding effluent (typically 2 mg/l BOD and 2 mg/l Sus. Sol.). The effluent is heavily chlorinated, pH adjusted, and corrosion inhibitors added.

The use of treated municipal effluent for boiler feed water makeup is practiced at three Texas locations; Big Spring, Lubbock, and Odessa, all of which are described in field investigation reports contained in Appendix A. Since water quality criteria is very high for boiler feed makeup water, the effluent must be extensively treated by the industrial user prior to use. At Southwestern Public Service Company, Lubbock, Texas, for example, TDS and hardness are reduced to less than 1 mg/l with pH adjustment, reverse osmosis, followed by demineralization with cation and anion exchanges, and a mixed bed exchanger for final polishing. For low pressure boilers clarification, filtration and softening is a typical treatment sequence, and demineralization is not used.

Three plants reported using reclaimed sewage effluent for processing purposes in the mining and steel making industries. Two Arizona plants utilize the effluent in the mining of copper. Bethlehem Steel Corp. uses small amounts for a variety of processes within its' fully integrated iron and steel plant in Baltimore, Maryland. Specific uses include gas cleaning, quenching, mill roll cooling, bearing cooling, process temperature control, direct process, de-scaling systems, mill hydraulic systems, fire protection, air conditioning, and road equipment washing.

Most industrial users of treated municipal effluent are in the semi-arid southwestern states where water costs are relatively high and fresh water quality tends to be poor in terms of TDS and hardness. Several of the Texas plants do not have an adequate alternative source of water and are totally dependent upon their sewage effluent supply. The others, however, have chosen to use reclaimed water because it is the cheapest source to serve their needs.

The cost of reclaimed water may be divided into two parts. First, the cost of procuring the reclaimed water, including payments to the municipality, construction of effluent transportation facilities, and all other costs required to deliver the effluent to the industrial plant site. Second, the cost of treating the reclaimed water to make its' quality suitable for the intended use.

Additional treatment costs generally comprise the largest portion of the cost of reclaimed water use to industry. The treatment costs depend upon the end use quality required, the quality of the sewage effluent, the degree of treatment required, the quantity of water treated, and other factors. For cooling water use in recirculating systems, the reported industry treatment costs varied from $100/MG to $550/MG.

Recreational Reuse

The recreational reuse chapter describes the three major recreational lake reuse projects in the United States, i.e., Santee, Tahoe, and Lancaster, California. Reclaimed waste water lakes used only for incidental fishing are described in a later chapter.

Each of the recreational lake projects described has provided important background for advances in waste water treatment.

The Santee County Water District lakes project is justifiably famous for its' pioneering work. Since 1961, the Santee Lakes have been used progressively for recreational activities involving increased human contact as laboratory results and epidemiological information indicated that such activities could be conducted without health hazard. The lakes are now used for boating and fishing with associated activities along the shoreline but are not open for whole-body water-contact sports. In 1965, an area adjacent to one of the lakes was equipped with a separate flow-through swimming basin which used reclaimed water that was given additional treatment by coagulation, filtration, and chlorination.

The best documented tertiary treatment process in the nation is found at Lake Tahoe, California where five tertiary treatment steps are combined to provide exceptionally high quality effluent. Activated sludge effluent is subjected to chemical treatment for phosphate removal, nitrogen removal, filtration, carbon adsorption, and chlorination. This plant also utilizes advanced sludge handling techniques, lime recalcination and carbon reactivation.

The treated effluent is pumped 14 miles through a lift of 1,470 feet, and then flows through gravity pipeline an additional 13 miles to Indian Creek Reservoir. Indian Creek Reservoir has a capacity of 3,200 acre feet. It is approved for body contact sports (swimming) and is reported to boast excellent trout fishing.

An interesting new project is located at Lancaster, California, where since 1971, the Sanitation Districts of Los Angeles County have sold renovated wastewater to the county of Los Angeles for use in a chain of three recreational lakes. The lakes have a capacity of 80 MG and serve as a focal point for the Counties' 56 acre Appolo Park. The park, located near Lancaster, California, was opened to the public in 1973 and features fishing, boating, and picnic areas.

During 1973, an average of 0.5 mgd of renovated wastewater for the Appollo Park lakes was supplied by the District's Renovation Plant No. 14 near Lancaster, California.

Treatment at Lancaster consists of a series of eight oxidation ponds followed by flocculation and sedimentation for removal of phosphates, suspended solids and algae; filtration to polish the effluent; and chlorination.

Each of the three recreational projects briefly described above is unique but they share much in common. All have found it technically feasible to consistently produce effluent meeting drinking water coliform standards. All practice phosphate removal for algae control and filter the effluent to reduce turbidity. Many species of fish have been grown successfully, including trout.

Domestic Reuse

Great controversy surrounds the subject of domestic reuse of wastewater for potable purposes. Much less opposition is voiced to non-potable domestic reuse, e.g., toilet flushing. It is not within the scope of this study to enter into the controversy. This report briefly describes the well-known operation at Windhoek, South West Africa, which is the only current example of direct potable reuse of municipal wastewater. In addition, the non-potable domestic reuse program managed by the National Park Service at Grand Canyon National Park is described in detail in Appendix A, Field Investigation Reports.

The Grand Canyon domestic reuse operation provides an average of 30,000 gpd through a separate distribution system for toilet flushing, car washing, irrigation, construction, and car watering. Major tertiary treatment given the activated sludge effluent is anthracite filtration and heavy chlorination. Cost to the user for the reclaimed water is $1,000 to $1,750 per MG. This premium price can be obtained because fresh water sells for $2,450 per MG.

Fish Propagation and Farming

The study did not locate any commercial fish farming ventures using reclaimed wastewater in the United States.

Although various species of fish exist in numerous municipal wastewater treatment lagoons, stocking of effluent lakes and ponds for public recreational fishing was reported in only eleven locations in this country. The fish species range from fathead minnows, raised for bait in Michigan oxidation pond, to rainbow trout stocked at Indian Creek Reservoir, fed by effluent from Lake Tahoe.

Fish kills have resulted from depleted oxygen or the presence of ammonia at some locations. Other potential problems can result from the presence of pathogenic bacteria, heavy metals, and pesticides. Several tables are provided in the chapter which detail concentrations of various constituents reported to be lethal to fish.

ECONOMIC FEASIBILITY OF WASTEWATER REUSE

Municipal wastewater reuse cost benefit analysis may be viewed from a local, regional, and national basis. A broad evaluation of wastewater reuse economic feasibility requires consideration of both water supply management and waste treatment management systems.

On a national basis, EPA, and many other agencies and organizations, support the continued development and practice of successive wastewater reclamation, reuse, recycling, and recharge as a major element in water resource management, providing the reclamation systems are designed and operated so as to avoid health hazards or environmental damage. The Federal Water Pollution Control Act Amendments of 1972 emphasizes a much broader consideration of wastewater reuse in the development and implementation of waste treatment management plans than has been given in the past. EPA encourages the incorporation of wastewater reuse facilities in municipal wastewater systems whenever such facilities are: (a) cost-effective, and (b) will result in no greater pollution effects to receiving waters than if wastewater reuse were not employed. As shown by this study, only a small percentage of municipal wastewater is presently reused in this country. On a national basis, it will be beneficial to increase reuse whenever possible within the technological and economic restraints stated above.

Cost-benefit analysis of municipal wastewater reuse on a regional and local basis is complex, and a need exists for development of detailed procedures and methodologies for economic evaluation of wastewater reuse. Each site and each area is unique. Based on this study, however, preliminary guidelines are presented below which list the major considerations involved in the reuse economic feasibility analysis.

An outline for the essential components of a complete economic analysis is given below. Following the outline, a brief discussion of each major component is presented, with examples from this study to illustrate applicable situations.

OUTLINE OF CONSIDERATIONS REQUIRED FOR ECONOMIC ANALYSIS OF MUNICIPAL WASTEWATER REUSE

A. Fresh water considerations, present and future

    1. Demand: in terms of quality, volume, and reliability for

        a. Domestic

        b. Industrial

        c. Irrigation

        d. Recreational

        e. And other purposes

    2. Supply: quality, volume, accessibility, reliability, and resultant cost to meet anticipated demand of 1.a through e.

    3. Legal or contractural restraints: e.g., a binding contract to purchase a minimum quality of fresh water from an existing water development project.

B. Municipal wastewater treatment considerations, present and future.

   1. Volume and quality of raw sewage

   2. Control of industrial sources contributing constituents potentially detrimental to reuse

   3. Differences in treatment and effluent conveyance facilities required to discharge to either receiving waters, land, or various potential reuses.

      a. Capital improvements, including effect of federal and state construction grants

      b. Operational costs

      c. Environmental considerations

   4. Legal or contractural constraints; e.g., water rights requiring return of certain volumes of effluent to a water course.

C. Reclaimed wastewater market considerations, present and future.

   1. Potential customers for irrigation, industrial, recreational water, both public and private.

   2. Volume, quality, and reliability requirements of potential reusers.

   3. Effluent transportation and storage facilities required.

   4. Additional treatment and/or volume, if any, required by the reuser above that necessary for the fresh water supply.

      a. Capital improvements

      b. Operation

   5. Additional treatment, if any, required by the reuser before discharge of his wastewater, above that necessary when using the fresh water supply.

   6. Potential revenues from sale of effluent to reusers.

D. Development of an analytic framework to complete an economic analysis of municipal wastewater reuse and feasibility using reasonable assumptions for capital financing costs, life of capital improvements, future changes in water demand and wastewater treatment requirements, and so forth.

A. Fresh Water Considerations

In most areas the present volume demand for fresh water for various purposes is readily available information. Future water demand projections are also usually available through the agencies responsible for water supply, or can be easily developed from existing planning data. A projection of water supply needs over a period of 20-30 years is desirable and it is important that estimates be made of what percentages of the demand are attributable to irrigation (other than private home landscaping), industrial (particularly large water using industrial complexes), power generation, and recreational lakes (especially in the arid areas.)

The existing and projected quality of alternate water supplies is often an important consideration in the economics of wastewater reuse. The potential user in deciding between alternate water supplies is interested in what additional treatment and handling costs he will incur because of quality differences between fresh water and reused water. For example, in all cases of reuse for cooling tower makeup water reported in this study, the user paid a penalty in extra treatment and chemicals required over that required for fresh water. For many irrigation applications, the quality difference is less important.

The volume reliability of the fresh water supply may be inferior to the reclaimed wastewater. In an area experiencing a water shortage, domestic needs will normally be met first, with agriculture and industry having lower priority. In Odessa, Texas, the El Paso Products Company deliberately chose to purchase reclaimed water for cooling and boiler feed makeup because the municipal effluent is a more reliable source than the public or private water supply. Similar situations exist at other cities in Southwest Texas.

The present and future purchase price of fresh water is a paramount factor in an economic analysis of wastewater reuse. In areas where fresh water is cheap and abundant, the reuse of municipal wastewater is less attractive. Conversely, in areas where fresh water is expensive, there is strong incentive for reuse. To take an extreme example, at Grand Canyon Village, Arizona, the purchase price of fresh water is $2,450/MG and reclaimed wastewater is used for many purposes including toilet flushing. In some cases, the reuse project can be justified on the basis of an expected increase in the future cost of fresh water. The Contra Costa County Water District near San Francisco is planning extensive industrial reuse of municipal wastewater in spite of the fact that at 1973 prices the fresh water costs less than the treated reclaimed water. The District has projected ahead and determined that the reuse of wastewater now will result in lower overall water management costs a few years hence.

Legal or contractural requirements to pay for water supply improvements or to purchase a minimum quantity of imported water may influence some communities in their consideration of wastewater reuse. Many California areas, for example, are obligated to purchase a minimum quantity of water annually from large water importation projects. Unless the community can modify its contractural obligation to purchase fresh water, a large scale reuse program may be impractical.

B. Municipal Wastewater Treatment Considerations

The volume and quality of the sewage generated by an area to some extent determines what types of reuse applications are feasible and, in addition, has an effect on treatment costs because of "economy of scale." Generally, a community must prevent the excessive discharge into its' collection system of contaminants which survive the treatment process and are detrimental to reuse applications. For example, many communities using municipal wastewater for irrigation have ordinances preventing discharge of home water softener brines into the sewers. Similar restrictions against wastes containing heavy metals are prevalent. In some areas, such as Big Spring, Texas, excessive infiltration of high TDS water into a deep trunk sewer renders most of the municipal effluent unsuitable for industrial or irrigation reuse.

An important cost factor in evaluating reuse are the differences in treatment facilities required to discharge to either receiving waters, land, or various potential reuses. This study showed, however, that very few of the municipal treatment plants supplying effluent for reuse provide greater treatment than would be necessary for alternate wasting of the effluent to receiving waters. In some cases of irrigation and industrial reuse, the municipal effluent is poorer in quality than would be required by state agencies for direct discharge to receiving waters, e.g., Bakersfield, California and Big Spring, Texas. These municipalities have enjoyed reduced treatment costs because their effluent is reused.

Expensive facilities may be required to transport the wastewater to the reuser. The treatment plant is usually located at the lowest elevation in its' service area and very near to receiving waters. A force main, pump station, and storage facilities are often necessary to convey the treated effluent to the reuser.

If the reuse requirement is periodic or seasonal, large effluent storage ponds may be necessary. Occasionally, ponds must be aerated to maintain effluent quality.

The results of our questionnaire response indicated that in the majority of existing reuse operations, the reuser paid for the effluent transportation and storage facilities. The trend has reversed in recent years, however, because of the availability of federal and state construction grants to municipalities.

Legal or contractural constraints are important in some locations because the reuse of wastewater instead of discharge to a receiving stream is complicated by water rights of downstream users. Water rights laws are usually based on a priority system whereby river waters are subject to appropriation. Prior to initiation of a reuse program such constraints should be investigated and resolved. For example, the city of Denver, Colorado, which is planning a major municipal wastewater reuse program, has entered litigation to resolve water rights questions raised by the planned reuse program. The city of Phoenix, Arizona, constructed an effluent transport canal and provided assurance of a certain quantity of effluent to a large downstream agricultural user under prior rights laws. Legal or contractural restraints may effect the feasibility and economics of wastewater reuse, but can usually be resolved.

C. Reclaimed Wastewater Market Considerations

Obviously, a municipal wastewater reuse program must have customers for its' reclaimed water to be successful. It appears from the results of this study that generally municipalities have not sought out potential reusers, particularly among private industry. Rare is the municipality which thinks of its' effluent as a commodity to sell rather than a nuisance to waste. Yet, reused water has enormous potential for increasing the water resources of individual localities and the nation. If reclaimed wastewater is used to satisfy demands for non-domestic uses of water wherever feasible, the fresh water thus saved will be able to satisfy much of the future increase in demand for general water supply.

One of the first places for a municipality to look is at its' own municipal activities. Municipal power generation stations, golf courses, parks, school grounds, farms, and recreational lakes are all successfully using their own treated municipal effluent as a water supply. Other governmental agencies, e.g., county, state, and federal, are also excellent prospects to purchase reclaimed water.

Private irrigation reuse sales opportunities are prevalent in most areas. Private farms, orchards, and golf courses are all amply represented among existing reusers listed in this report. Financial arrangements in effect between the municipality and the irrigator range from charges based on volume used to a flat fee negotiated annually. Most of the existing irrigation reuse operations are located very near the treatment plant. It appears that more emphasis might be given to selling effluent to large irrigators remote from the treatment plant.

There are only twelve private industrial reusers of municipal effluent in the nation and two of these are "company towns" for large copper mines. Undoubtedly, many opportunities for industrial reuse of municipal wastewater are being ignored, especially for cooling purposes. As the results of this study amply demonstrate, municipal effluent can be successfully used for both once-through and recirculating cooling systems. There is extra cost to the industry in treatment and chemicals in the use of reclaimed water instead of fresh water, however, in many cases this extra cost is offset by the lower cost of the used water. The potential market is staggering. The power industry alone uses over 75 billion gallons per day of cooling water.

Looking at the reclaimed wastewater market from the reusers point of view, it appears that generally the reuser is most concerned about what will be the real total cost to him of using effluent instead of fresh water. He is willing to consider the use of reclaimed water if the cost savings justify his having to cope with any additional problems associated with reclaimed water use. The potential extra costs of the problems may include the following:

- The effluent may be insufficient volume at times. For example, during a hot summer spell there may be insufficient effluent for adequate irrigation or cooling water makeup. The city of Burbank supplies cooling water to a nearby power plant, and occasionally low effluent volume late on a summer night is insufficient to satisfy the power plant requirement. Adequate storage facilities can normally overcome volume supply-demand problems. Conversely, as previously indicated, the reclaimed wastewater supply may be the more reliable in water short areas.

- The effluent is of lower quality than fresh water, and will show occasional variability in quality resulting from sewage treatment plant upsets. The industrial reuser for cooling will normally incur extra cost for the use of lower quality water, because of increased treatment required and need for greater volume. The greater volume may be necessary because the higher TDS of the reclaimed water allows fewer cycles through the cooling system before discharge. The occasional variable quality may necessitate extra safeguards in personnel vigilance and quality monitoring instrumentation to protect the industrial user.

  The irrigation reuser is normally less concerned about occasional changes in quality (except health hazards). His only extra cost may be increased volume required to prevent buildup of TDS, sodium, chlorides, etc. in the soil root zone. Offsetting this may be the fertilizer value of the effluent, which has been estimated at $18/MG in the irrigation chapter of this report.

- Effluent transportation and storage facilities in many cases may be the single largest extra cost to the reuser. The magnitude of the cost is dependent upon many factors, including distance, elevation difference, storage volume, pipe diameter, etc. In some cases equivalent facilities would be required for fresh water supplies so no extra cost is incurred for wastewater reuse.

- A problem in some instances to the reuser is the discharge of his wastewater. Because he is using a lower quality water supply, his wastewater discharge in turn may have difficulty meeting the regulatory agency standards. A common example of this situation is cooling tower blowdown which has concentrated contaminants such as TDS, heavy metals, chlorides, etc. many times over their levels in the cooling makeup water. The problem was approached in several ways by respondents to this study. Several industrial plants simply have no discharge, but instead dispose of their final waste by evaporation or deep well injection. One power generation station proved to the local regulatory agency that its' use of treated sewage effluent resulted in a lower overall discharge of contaminants to the environment; though the discharge from the power station is more concentrated, the discharge from the nearby sewage treatment plant is eliminated entirely.

- Revenues from sale of effluent are an important factor in the economic evaluation of a wastewater reuse program. The results of this study show that generally most industrial reusers are paying for the wastewater they use on a volume basis, and most irrigation reusers are getting the wastewater free or for a very minimal sum. Price is a relative factor. The price of reclaimed wastewater must be compared to the price of alternative supplies of water that will meet the customers needs and to whether or not he can afford to pay the price being asked, and still compete on the open-market with his product.

The cost of additional treatment, transport and storage to meet a customers' special needs is a further restraint on price setting. No matter how conservation minded a community is, the use of reclaimed water will be severely limited if the net cost to the community for disposal via reclamation exceeds that of alternative method of disposal which is also commensurate with regulatory requirements.

D. Development of an Analytic Framework to Complete an Economic Analysis

Development of an analytic framework to complete an economic analysis is necessary to tie the various considerations described in the previous pages together and arrive at a rational answer to the feasibility of wastewater reuse. A need exists to develop detailed procedures and methodologies to accomplish this. On a simplistic basis, however, wastewater reuse is probably worth seriously investigating whenever one or more of the following conditions is met:

- Existing fresh water supplies are limited and substantial future expenditures are contemplated to develop additional supplies.
- Existing fresh water supplies are relatively expensive.
- Private or public developments with need for large volumes of water exist in the area.
- The treatment provided the wastewater produces an effluent of very high quality which is now wasted into receiving waters.
- Regulatory agencies are planning to require a higher degree of treatment for discharge to receiving waters, such as nutrient removal.

Again on a simplistic basis, the economic feasibility of wastewater reuse can be viewed from the standpoint of both the municipality and the potential reusers as a series of pluses and minuses. A favorable situation will have both the municipality and the potential reuser on the plus side.

For the municipality the balance sheet would include the following:

Pluses

1. Savings in fresh water supply facilities which do not have to be built because reuse lessens the demand upon fresh water sources.
2. Savings in sewage treatment and disposal costs, if any, for discharge to reuse instead of discharge to receiving water.
3. Savings, if any, in construction of raw sewage trunk sewers resulting from construction of a sewage reclamation plant at an upstream location in the collection system.
4. Revenues received from the sale of reclaimed water.
5. Environmental advantages, i.e., discharge of nutrients to land instead of receiving waters.
6. Public relations advantages.

Minuses

1. Extra costs for sewage treatment and effluent transport and storage, if any, for discharge to reuse instead of discharge to receiving waters.
2. Extra costs, if any, for administration of a reuse program, e.g., billings, handling complaints, etc.
3. Legal restraints, e.g., prior water rights.
4. Salt, nitrate, and other contaminants build-up in the basin resulting from recycle, especially in cases of irrigation reuse.

For the reuser, the balance sheet would include the following:

Pluses

1. Lower cost water supply.
2. If an irrigator, higher fertilizer value of reclaimed water.
3. In some cases, more dependable water supply.

4. Beneficial public relations.

Minuses

1. Extra cost for treatment, conveyance or storage, if any, over that required for fresh water supply.
2. Extra volume needed to accomplish similar purposes, if any, over that required for fresh water supply.
3. Extra costs, if any, for reuser to discharge his wastewater as a result of using reclaimed water instead of fresh water.

Both the municipality and the potential reusers should analyze reuse on the basis of future as well as existing conditions. Rising fresh water costs and more stringent wastewater discharge requirements in the near future may make reclamation a practical solution now.

SECTION VIII

CONCLUSIONS

- The reuse of municipal wastewater is being practiced on a continuing basis at about 358 locations in the United States. About 95 percent of these operations are located in the semi-arid Southwest states of Texas, California, Arizona, New Mexico, Colorado, and Nevada. Total reuse volume is approximately 133 billion gallons annually, exclusive of groundwater recharge which was not included in the scope of this study.

- Treated municipal wastewater is being successfully utilized for irrigation of a wide variety of crops and landscaping, industrial cooling and process water, recreational lakes, and fish propagation. At one U.S. site treated effluent is used for non-potable domestic purposes (e.g., toilet flushing).

- Irrigation with municipal wastewater is practiced at approximately 338 locations and utilizes about 77 billion gallons annually. The majority of the crops are not for human consumption. Examples are cited, however, of the irrigation of many varieties of crops for human consumption and irrigation of landscaping with human contact (e.g., golf courses).

- Approximately one quarter of the treatment plants furnishing wastewater for irrigation in 1972 provide only primary treatment. The remainder provide secondary treatment and in a few instances tertiary treatment. Reported quality, both organic and inorganic, of effluent used for irrigation varies widely. With proper crop selection and irrigation management even very poor quality effluents are used successfully.

- Important components of a successful irrigation program include adequate storage, well engineered runoff control, odor and insect nuisance prevention, protection of the public against unsafe exposure, and good lines of communication between the municipal supplier and the irrigator. Many existing programs lack one or more of these safeguards and guidelines for proper design and operation should be adopted and enforced by responsible regulatory agencies.

- Many irrigation operations are primarily intended as a method of disposal. If there was no runoff from irrigated areas into surface waters, regulatory agencies paid little attention to the irrigation wastewater quality. In recent years, however, there has been growing concern over the possible effect upon groundwater resources from infiltration of pollutants contained in treated sewage used for irrigation. It is probable that in the future, effluent quality standards for such use will become more stringent.

- Approximately 20 percent of the municipalities supplying treated wastewater for irrigation receive revenue from sale of the wastewater. At those municipalities which do charge, weighted average user charges are \$6/MG for primary effluent, \$11/MG for secondary effluent, and \$76/MG for tertiary effluent. As a whole, municipalities are apparently not charging enough for the effluent they supply, however, any revenue is more than would be received if the effluent were simply discharged to waste.

- Only 15 industrial plants are presently reusing municipal wastewater in the U.S. These 15 facilities include three city-owned power plants, so private industry is represented by only 12 plants. Obviously, numerous potential industrial reuse opportunities remain unrecognized.

- Approximately 53.5 billion gallons of treated municipal effluent is reused annually by industry. Cooling water use accounts for 98.5 percent of the total volume, with the remaining small increment used for boiler feed water makeup, process water in copper mining, and miscellaneous process uses.

- Treated municipal wastewater is being used successfully for cooling water makeup at 12 industrial plants in the U.S. Cooling water technology is complex and the use of reclaimed sewage presents special problems of treatment to the industrial operator. Unless the municipal effluent is of exceptionally high quality, further chemical treatment is required to remove phosphates, organics, and suspended solids prior to use in the cooling tower system. Municipalities and industries have demonstrated the ability to cooperate in managing reuse programs to the benefit of both. Probably the greatest single undeveloped reuse potential is the increased use of municipal effluents for industrial cooling purposes.

- Generally, from an industry point of view, the municipal wastewater is in direct competition with fresh water. In order for reuse to be attractive, either the total cost of purchasing, transporting, and treating the wastewater must be less than the total of equivalent costs for fresh water, or the reclaimed wastewater must provide a more dependable supply than the fresh water system. At seven locations where costs could be determined, the total cost of using effluent ranged from $143 to $675/MG with a median of $240/MG.

- There are three U.S. municipal treatment plants which provide treated effluent for major recreational lake projects. They are located in California at the cities of Lake Tahoe, Santee, and Lancaster. All provide some degree of tertiary treatment, and have been extensively covered in the technical literature. Each project has been successful in achieving most of its' goals in terms of consistantly providing high quality effluent which poses no hazard to the public utilizing the lakes.

- Reported treatment costs, including capital amortization, for supplying tertiary treated effluent for recreational lakes range from $150/MG at Lancaster, California to $882/MG at Lake Tahoe. Lake Tahoe costs are misleading because the treatment plant is operating at less than half design capacity.

- Successful fish propagation in treated municipal effluent has been reported at several locations in addition to the major recreational lakes listed above. There is little or no information available, however, regarding the suitability of the fish for human consumption.

- The only active domestic reuse operation in the U.S. is at Grand Canyon Village, Arizona where about 30,000 gpd of treated municipal wastewater is used for toilet flushing, car washing, and other non-potable uses.

- Only a small percentage of municipal wastewater is presently reused in this country. To conserve our national fresh water resources government and the public will be wise to strongly support the expanded practice and continued development of municipal wastewater reclamation.

SECTION IX

RECOMMENDATIONS FOR ADDITIONAL RESEARCH

1. A major need to supplement this report is a state-of-the art study of groundwater recharge, using reclaimed wastewater for water supply augmentation, salt water intrusion barrier and oil field flooding. The approach for the additional work would be similar to that used for this study.

2. Work should begin on preparation of an EPA technology transfer seminar publication on wastewater reuse, similar to EPA publications on upgrading lagoons, nitrification, and denitrification facilities, etc. Such a publication would have widespread distribution and create interest in reuse.

3. Implementation of a series of comprehensive, in-depth evaluations of existing reuse operations would be of immense value. This report is a broad overview, almost entirely dependent for its information upon data supplied by the existing reuse operations. What is needed is a detailed technical and economic field study involving extensive on-site analysis of various phases of representative reuse operations. Irrigation, industrial, groundwater recharge, and recreational lake uses should be represented.

4. Preparation of a study showing detailed methodologies and procedures for economic evaluation of a municipal wastewater reuse program.

5. The role of incentives for reuse on a federal, state, and local level should be studied. Many of the benefits from local wastewater reuse are felt on a regional or national level, and perhaps local reuse operations should be compensated accordingly. Similarly, the reuser is benefitting the community and perhaps should be rewarded in some manner, e.g., lower industrial waste discharge surcharge, etc. As part of this work, the relationship between treatment plant construction grants and potential reuse programs should be analyzed. There is a danger that federal and state grants will

contain provisions which tend to inadvertently discourage reuse. Possibly this recommendation could be incorporated into 4. above.

6. Continued basic research is needed into the potential health hazards of the use of reclaimed wastewater for purposes of direct potable reuse, total body contact, edible fish propogation, and irrigation of crops for human consumption. Of particular interest is the fate of the refractory organics, heavy metals and pathogenic organisms during reuse. Is there a buildup? Is there a health hazard? At what concentrations? Etc.

7. Since cooling water is the predominant industrial use for reclaimed wastewater, now and in the future, more needs to be known about optimizing the technical and cost relationships between effluent quality, user treatment required, and cooling system operational procedures (e.g., number of cycles, corrosion control, etc).

8. Continued basic research is needed in the area of advanced treatment methods for removal of contaminants detrimental to reuse. Partial demineralization of effluent must be made less expensive, if possible. An inexpensive method of removing boron from potential irrigation water is needed. The effectiveness of disinfection with and without filtration should be determined for various qualities of effluent. Some municipalities feel their effluent could only be reused if it were filtered, because chlorination alone will not produce adequate bacterial kills.

9. Dual potable and non-potable water system technology and economics is of interest, particularly the factors bearing on the feasibility of a dual system, and the necessary design criteria to protect the public health.

10. Basic research should continue in the development of simple, rapid procedures and reliable instrumentation for measurement and monitoring of bacteria, chemicals, and toxic agents in reclaimed water. Other than an occassional chlorine residual recorder or turbidimeter very little instrumentation to monitor reclaimed water was reported by this study. Bacteriological tests would be more valuable if the time lag between sampling and results were shortened.

SECTION VIII

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SECTION XI

APPENDICES

APPENDIX A

FIELD INVESTIGATION REPORTS

GRAND CANYON VILLAGE, ARIZONA

INTRODUCTION

Grand Canyon Village, located on the south rim of the Grand Canyon, is the only reported location in the United States where reclaimed sewage effluent is utilized as a non-potable domestic water supply. An average of 30,000 gpd (approximately 7 percent of the total water demand) is used during the May through September high-use season for: toilet flushing, car washing, irrigation, construction, and stock watering.

MUNICIPAL TREATMENT PROCESSES

Reclaimed water is supplied to the village by the village tertiary treatment plant. The plant, built in March, 1972, treats an average of 0.22 mgd during peak season, of which approximately 14 percent is reclaimed for non-potable use. Industrial wastes from a large laundry comprise only a small fraction of the influent raw sewage flow and exert no significant effect on the treatment process.

Figure A-1 diagrams the major treatment processes. Primary treatment consists of screening followed by comminution. The raw sewage then goes directly into one of three activated sludge aeration tanks which provide 5 hr detention time, MLSS concentration of 2,000 to 3,000 mg/l and 60 percent sludge recirculation rate. Gravity circular secondary clarification follows with an overflow rate of 600 gpd/sq ft. Aerobic sludge digestion is used followed by drying beds.

Tertiary treatment constructed in 1926 consists of filtration through anthracite coal beds (which are composed of 2.5 to 3.5 ft of various sized rock covered with 18 inches of coal), and chlorination to a residual of 5 mg/l chlorine. A covered concrete storage tank holds 0.3 mg and serves to meet the varying demands of the village. The reclaimed water is then pumped directly into the village distribution system, where a steel storage tank holding 0.1 MG provides constant pressure.

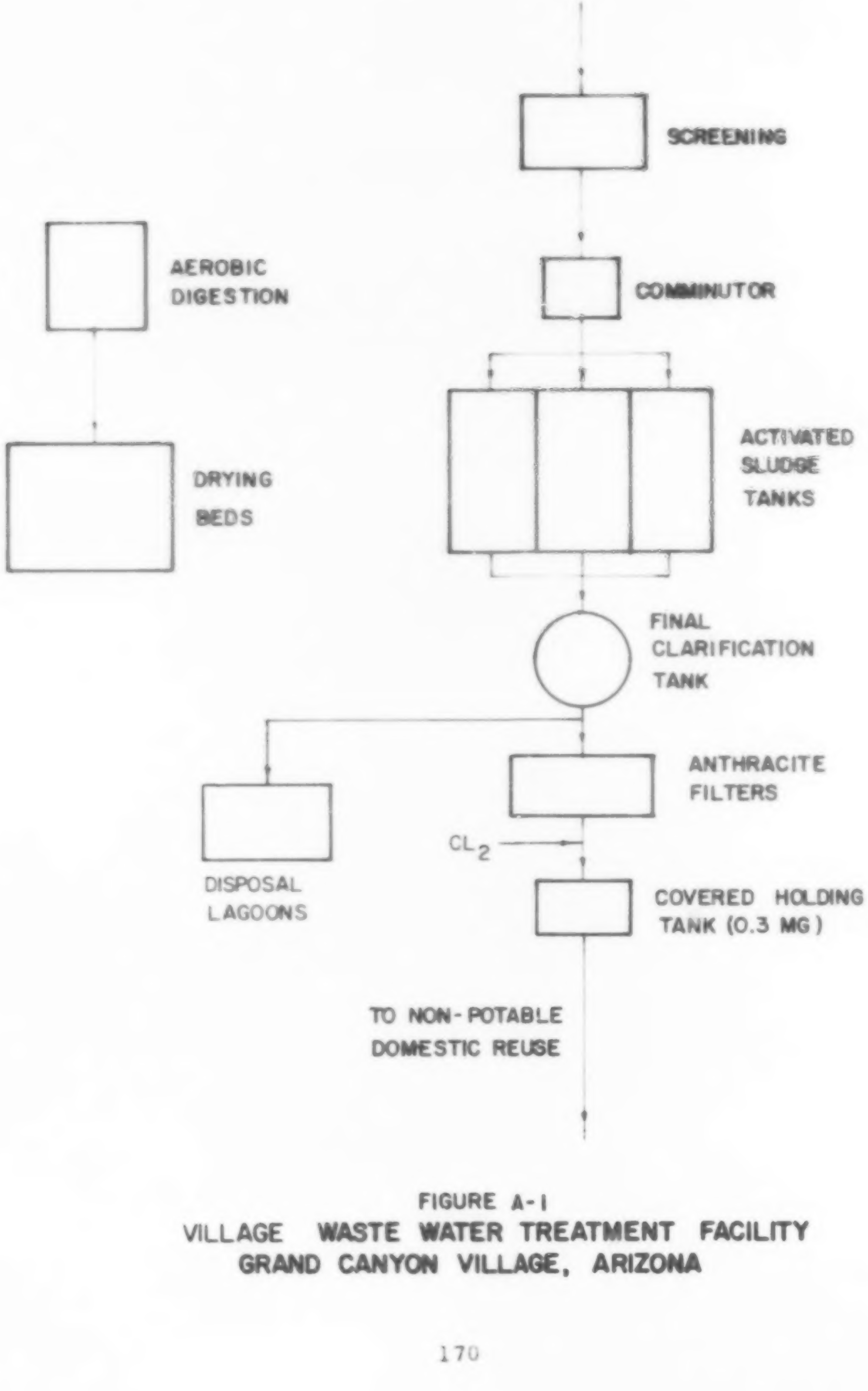
SCREENING
AEROBIC DIGESTION
COMMINUTOR
ACTIVATED SLUDGE TANKS
DRYING BEDS
FINAL CLARIFICATION TANK
ANTHRACITE FILTERS
DISPOSAL LAGOONS
CL2
COVERED HOLDING TANK (0.3 MG)
TO NON-POTABLE DOMESTIC REUSE

FIGURE A-1
VILLAGE WASTE WATER TREATMENT FACILITY
GRAND CANYON VILLAGE, ARIZONA

Typical final effluent characteristics are listed in Table A-1. The only reported effluent odor is a noticeable chlorine odor resulting from the high residual, that is maintained partly to discourage human consumption of the water.

Table A-1. AVERAGE EFFLUENT CHARACTERISTICS AT GRAND CANYON VILLAGE, ARIZONA

Characteristic	Concentration (mg/l)
BOD	10
SS	10
TDS	616
Cl	200
MPN	0
pH	6.9-7.2

After secondary treatment, the effluent remaining after the non-potable distribution system needs are met, is stored in a 6 MG evaporation lagoon.

REUSE PRACTICES

The largest single use of the effluent is for flushing public toilets in most of the older lodges, motels, dorms, and cafeterias within the village.

Irrigation of the high school football field and landscaping is another major use of reclaimed water, followed by vehicle washing and occasional use in road and airport runway construction. Table A-2 shows high and low reuse volumes for various activities. Use drops off during the winter months as tourist activity declines.

Table A-2. REUSE VOLUMES AT GRAND CANYON VILLAGE, ARIZONA

Use	Volume (gal/month)	
	High	Low
Public Toilets	1,050,000	321,000
Irrigation	515,000	19,000
Car Washing	26,000	3,200

The major problem reported with the reclaimed water operation is distribution. The distribution system for reclaimed water is old and piping is corroded. The existing system is already limited in area and becomes more so as old piping deteriorates and is abandoned.

If requested funds become available, park engineers are planning to replace and expand the reclaimed water distribution system and replace the tertiary treatment plant. Reclaimed water would then be made available to all private and public toilets for which an economic advantage could be shown. The potential use for reclaimed water is roughly 6 MG/month during peak seasons. Figure A-2 depicts the existing and future distribution plan for the village.

In addition to problems of distribution, other difficulties include minor occurances of sludge bulking and poor settling in the secondary clarifier. Low pressure resulting from insufficiently elevated reclaimed water storage tank was recently rectified by installation of a pneumatic pressure system to serve the higher points of use. Generally, the present system is considered very successful. There have been no reports of health or aesthetic problems due to reclaimed water use.

An improved and expanded system of wastewater treatment and distribution would ease the increasing demand on the precious fresh water supply of Grand Canyon Village. The success of this operation may interest other communities with critical water supply problems, to evaluate the advantages of domestic water reclamation and reuse systems. This is especially true for those future developments where costs of a parallel non-potable piping system would not be as prohibitive. At Grand Canyon, reclaimed water pipes were laid in the same trench with the sewers. All trenching is in solid rock.

ECONOMICS

Economics is of particular importance in the grand Canyon since geographic and climatic constraints to obtaining fresh water are severe. The land surrounding Grand Canyon Village is arid. Potable water must be piped 15 miles across the Grand Canyon from Roaring Springs and pumped 3,400 ft in elevation. As a result, fresh water cost is $2.45/1,000 gal. In addition, damage to the transmission pipe from falling rock along the canyon walls is common. Maintenance is difficult and costly, involving the use of helicopter air lifts and other unusual techniques. The Village's rapid population growth of approximately 6 percent annually increases the critical nature of the water supply problem. Maximum

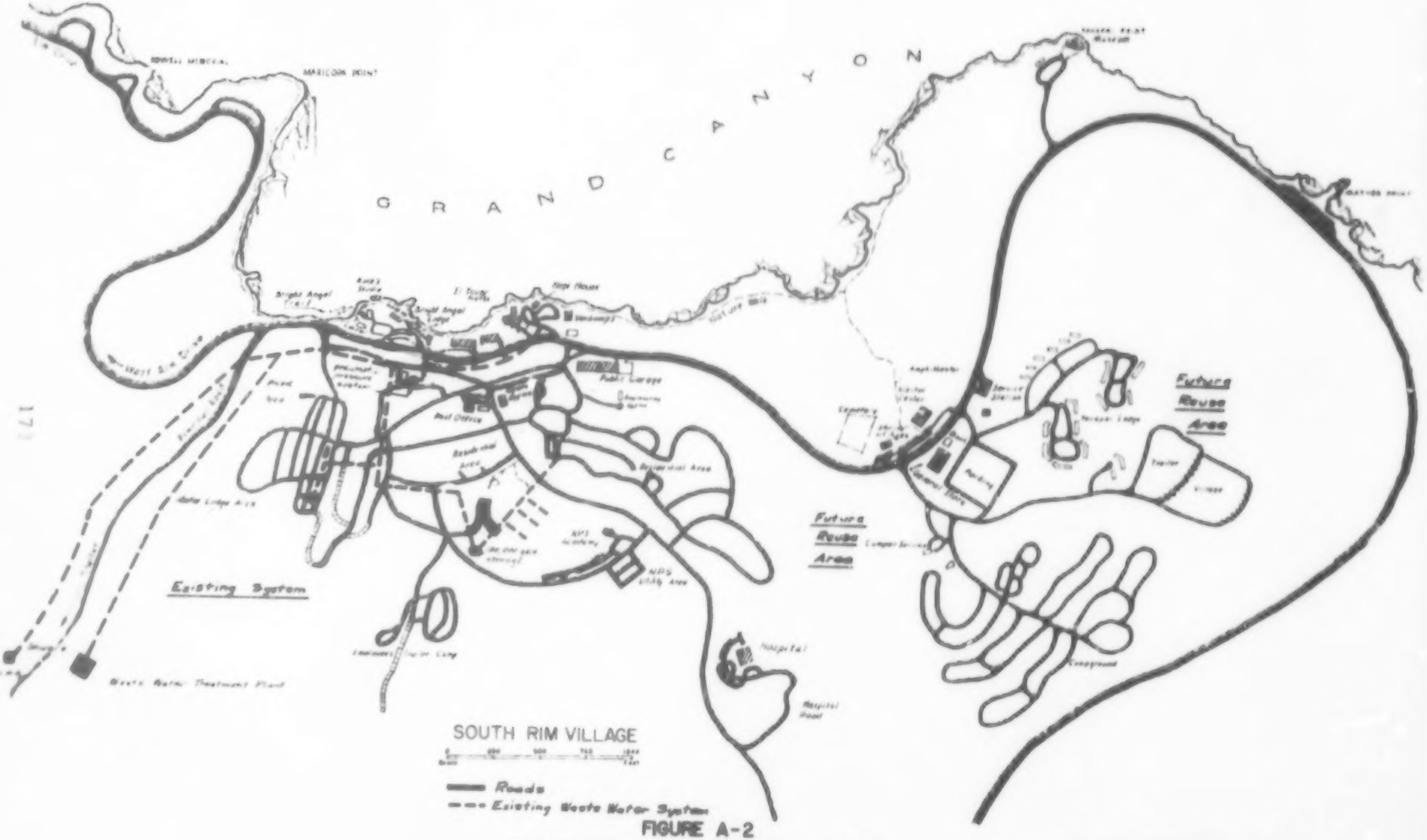
GRAND CANYON
Maricopa Point
Bright Angel Trail
Bright Angel Lodge
El Tovar Hotel
Hopi House
West Rim Drive
Public Garage
Post Office
Residential Area
Existing System
Waste Water Treatment Plant
NPS Academy
NPS Utility Area
Hospital
Hospital Road
Cemetery
Service Station
General Store
Parking
Trailer Village
Campground
Future Reuse Area
Future Reuse Area
SOUTH RIM VILLAGE
Roads
Existing Waste Water System

FIGURE A-2
EXISTING AND FUTURE REUSE
AT GRAND CANYON VILLAGE, ARIZONA

Reproduced from best available copy.

use of reclaimed water is economically feasible. Charges for reclaimed water are $1.00/1,000 gal when piped to a point of use where potable water is also available, and $1.75/1,000 gal for all other areas. The lower rate provides an incentive to use reclaimed water. Total revenue from sale of reclaimed water was $11,000 in 1971.

SCS Engineers estimates that the treatment cost of the wastewater is $2.58/1,000 gal. Sales of effluent reduce the village's treatment costs by approximately 5 percent. The remaining treatment costs are paid out of appropriated funds by the federal government.

PHOENIX, ARIZONA

INTRODUCTION

The municipality of Phoenix, Arizona has one of the nation's largest wastewater reclamation and irrigation programs. Approximately 35 mgd of secondary treated effluent is committed by contracts for irrigating crops, providing water to a 70 acre fish and game marsh, and for experimental reclamation purposes.

MUNICIPAL TREATMENT PROCESSES

Phoenix, Arizona operates two activated sludge treatment plants, the 23rd Ave. Plant which serves a portion of Phoenix, and the Multi-City 91st Ave. Plant which treats sewage from Phoenix and the surrounding cities of Glendale, Tempe, Scottsdale, Mesa, Youngtown, Sun City and Peoria. Industrial waste flow into the municipal plants comprise about 7 percent of the total volume, with the predominant waste coming from plating operations. Stringent industrial discharge standards which require the pretreatment of all industrial wastewaters discharged into the sanitary sewerage system, protect the treatment plants and insures an effluent suitable for reuse. Treatment provided at the two plants is nearly identical and only the 91st Ave. plant will be discussed in detail. Figure A-3 shows schematically the treatment and reuse operations.

The 91st Ave. plant treats 60 mgd of raw sewage. Primary treatment consists of screening followed by grit removal and four primary sedimentation tanks. The sewage then flows into four activated sludge tanks using step aeration with conventional spiral flow, 5 hr detention, and 2,100 mg/l mixed liquor solids concentration. Air is supplied at the rate of 1,300 cu ft per lb of BOD removed. Twenty-four secondary gravity clarification tanks with overflow rates of 530 gpd/sq ft provide final settling prior to discharge.

Water quality characteristics of the secondary effluent from the 91st Ave. activated sludge plant are tabulated in Table A-3.

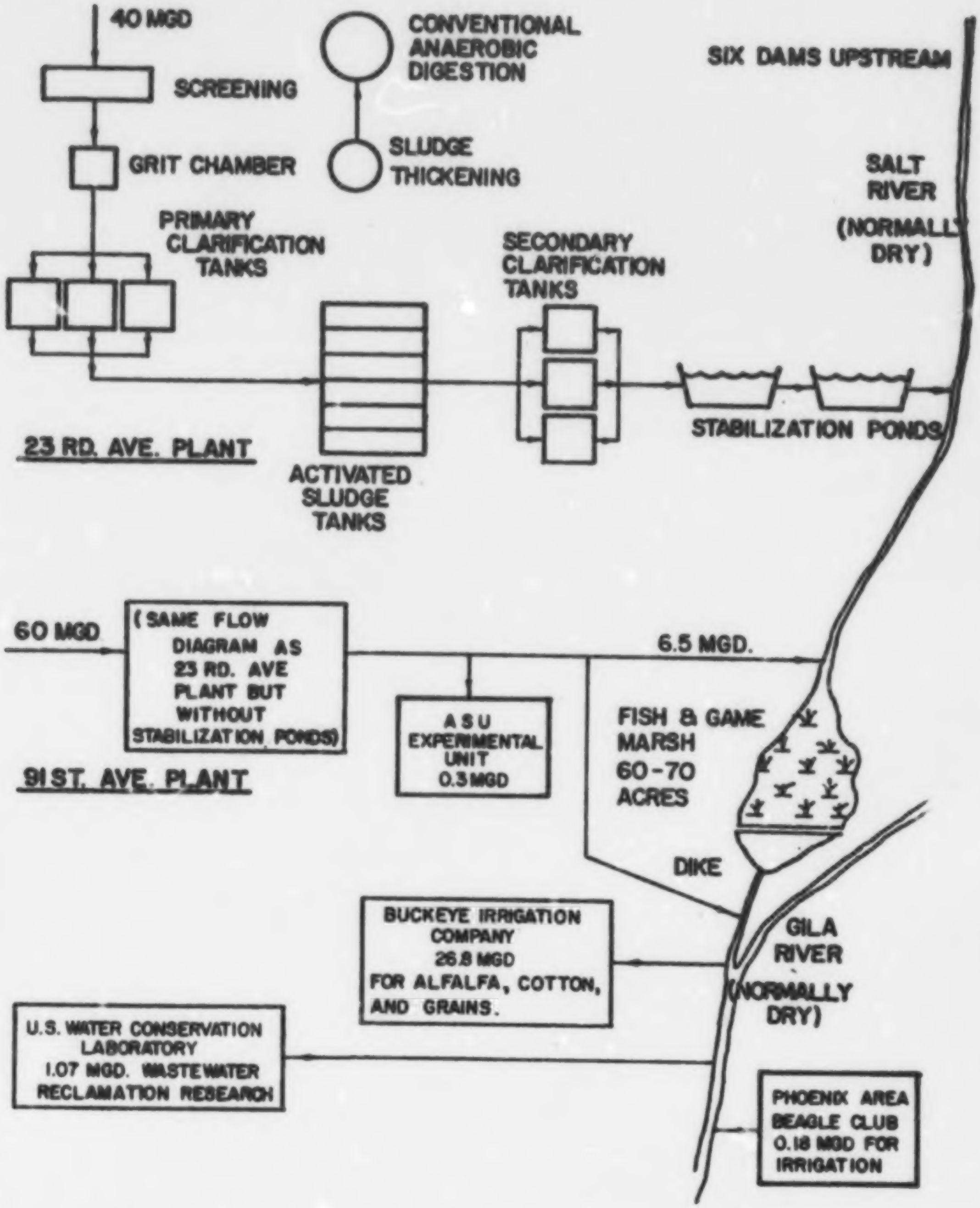
40 MGD
SCREENING
GRIT CHAMBER
PRIMARY CLARIFICATION TANKS
CONVENTIONAL ANAEROBIC DIGESTION
SLUDGE THICKENING
SIX DAMS UPSTREAM
SALT RIVER (NORMALLY DRY)
SECONDARY CLARIFICATION TANKS
STABILIZATION PONDS
23 RD. AVE. PLANT
ACTIVATED SLUDGE TANKS
60 MGD
(SAME FLOW DIAGRAM AS 23 RD. AVE PLANT BUT WITHOUT STABILIZATION PONDS)
6.5 MGD.
ASU EXPERIMENTAL UNIT 0.3 MGD
91 ST. AVE. PLANT
FISH & GAME MARSH 60-70 ACRES
DIKE
BUCKEYE IRRIGATION COMPANY 26.8 MGD FOR ALFALFA, COTTON, AND GRAINS.
GILA RIVER (NORMALLY DRY)
U.S. WATER CONSERVATION LABORATORY 1.07 MGD. WASTEWATER RECLAMATION RESEARCH
PHOENIX AREA BEAGLE CLUB 0.18 MGD FOR IRRIGATION

FIGURE A-3
MUNICIPAL WATER RECLAMATION AND IRRIGATION REUSE SYSTEM
PHOENIX, ARIZONA

Table A-3. TYPICAL MUNICIPAL EFFLUENT CHARACTERISTICS AT 91ST AVE. PLANT, PHOENIX, ARIZONA

Characteristics	Concentration (mg/l)	Characteristics	Concentration (mg/l)
SS	25	Ca	64
BOD	13	Mg	26
TDS	1,000	Fe	0
Total N	32	Na	125
NO_3	2	COD	50
NO_2	1	Hardness	268
NH_3	20	Alkalinity	316
PO_4	33	pH	7.4
SO_4	100	MPN	3.5×10^6
Cl	275		

Currently, an advanced tertiary treatment pilot system is being tried at the 91st Ave. plant in cooperation with Arizona State University to treat approximately 0.3 mgd of secondary effluent. The treatment involves two submerged biological filter units in series. This simple system is reported to consistently reduce BOD and SS concentrations below 1 mg/l. A smaller submerged biological filter pilot system at the 23rd Ave. plant is being fed raw sewage at the rate of 8,000 gpd. The effluent from this small operation has a BOD of about 1 mg/l and is being successfully used in hydroponic irrigation experiments with tomatoes, carrots, lettuce, and beans.

Further treatment of secondary effluent is provided only at the 23rd Ave. plant. One-hundred twenty acres of ponds provide this additional treatment and also serve as a sanctuary for hundreds of water fowl, including ducks, geese, herons, and smaller marsh birds. The 91st Ave. plant discharges directly to the dry Salt River bed.

REUSE PRACTICES

Reclaimed water reuse in Phoenix, Arizona, can be separated into four areas: (1) irrigation by the Phoenix, Arizona Beagle Club, 0.18 mgd; (2) irrigation by the Buckeye Irrigation Company, 26.8 mgd; (3) creation of a marsh for fish and wildlife refuge by the Arizona Fish and Game Department; and (4) advanced wastewater treatment experimentation, 1.07 mgd.

Effluent from the 91st Ave. plant, averaging 60 mgd, flows through an open, earth-lined channel to the normally dry Salt River bed. Approximately three miles downstream, the flow encounters a dike which causes a portion of the reclaimed water to form a marshy area of 70 acres. This area serves as a refuge for birds and other wildlife as well as a site for recreational fishing. Carp, Catfish, and Gambusia are among the species of fish life found in the refuge. Further down the river, the U.S. Water Conservation Laboratory extracts 1.07 mgd for experimentation, and the Buckeye Irrigation Company diverts 27 mgd for irrigation of alfalfa, cotton, and grains.

ECONOMICS

About 25.2 mgd is purchased from the Multi-Cities by the Buckeye Irrigation Company at $4.60/MG; however, an additional 1.6 mgd of Phoenix's reclaimed water flow is also diverted from the Salt River by the Buckeye Irrigation Company to satisfy a legal commitment. Total revenue to the Multi-Cities was $42,300 in 1972. Plans are being prepared for reuse as cooling water for nuclear power plants, the first of which is to be completed in about 1981. The Arizona Nuclear Power Project has been granted an option to purchase an ultimate volume of 140,000 acre feet of effluent per year.

The city of Phoenix has recently been offered an EPA Research Grant to construct and operate a soil filter system to reclaim about 15 mgd of effluent from the 23rd Ave. plant. This demonstration system, a larger version of the 1 mgd research unit now operated by the U.S. Water Conservation Laboratory downstream from the 91st Ave. plant, will produce water that is suitable for unrestricted agricultural use. It is intended that this water will be sold to the Roosevelt Irrigation District when the unit is placed in operation about July 1974.

BAKERSFIELD, CALIFORNIA

INTRODUCTION

The city of Bakersfield, California has reclaimed primary treated municipal wastewater for irrigation water since 1912. During 1972 the program irrigated 2,400 acres of corn, barley, wheat, alfalfa, cotton, and permanent pasture by utilizing the entire average effluent flow of 12 mgd from two municipal treatment plants located adjacent to the fields. The project demonstrates that irrigation with poor quality effluent is agriculturally feasible and economically attractive. The farmer realizes substantial savings in the purchase of water and the municipality gains economic advantages through low treatment costs. Of major significance is the resulting conservation of fresh water supplies in this water short area. Long-term effects upon groundwater quality, however, have not yet been thoroughly investigated.

A successful program requires knowledgeable crop management and a well balanced irrigation program. Sufficient water storage capacity should be available to meet variance in water demand for optimum results. A large capacity tailwater collection and recirculation system is required to prevent runoff of polluted irrigation water.

MUNICIPAL TREATMENT PROCESSES

The two Bakersfield primary treatment plants are located within 2,400 acres of irrigated fields and approximately 2 miles from the nearest residential development. The plants are very similar, consisting of screening, grit removal, and primary gravity clarification, followed by a holding pond. Conventional anaerobic sludge digestion is used. Dried sludge is composted with collected leaves and spread in city parks. The only significant difference in the two plant processes is the addition of pre-aeration prior to sedimentation at Plant No. 2. A schematic flow diagram of Plant No. 2 is shown in Figure A-4 and plant effluent characteristics are presented in Table A-4. The poor quality of the Plant No. 1 effluent is due to high influent BOD from dairy and poultry processing plants.

Table A-4. AVERAGE MUNICIPAL EFFLUENT CHARACTERISTICS AT BAKERSFIELD, CALIFORNIA

Characteristic (mg/l)	Plant No. 1 (3.6 mgd)	Plant No. 2 (8.4 mgd)
BOD	370	85
SS	118	26
TDS	630	324
Na	181	87
Cl	96	50
pH	7.0	7.4
PO_4	16	20
NH_3-N	29	23

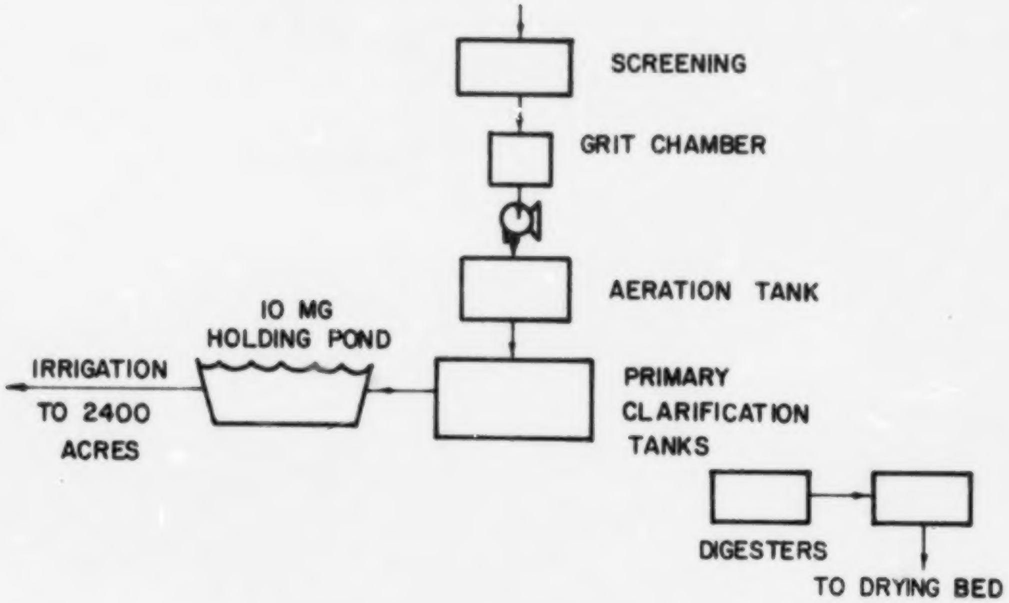
SCREENING
GRIT CHAMBER
AERATION TANK
10 MG
HOLDING POND
IRRIGATION
TO 2400
ACRES
PRIMARY
CLARIFICATION
TANKS
DIGESTERS
TO DRYING BED

FIGURE A-4
MUNICIPAL SEWAGE TREATMENT PLANT NO. 2
BAKERSFIELD, CALIFORNIA

REUSE PRACTICES

The irrigated fields surround the treatment plants and utilize all effluent from the plants. Ridge and furrow irrigation is used. No discharge of wastewater is allowed from the 2,400 acre farm. Management of tailwater (runoff from the fields) is a large operation involving storage in a 20 MG tailwater pond and pumping back to the irrigation system. This effort could be greatly reduced by increased storage capacity of effluent prior to irrigation.

In general, odors in the fields are not severe; however, mosquitos are ubiquitous throughout the irrigation system and pose a significant problem which is perpetuated by excess water ponding during the winter season. Mosquito abatement spraying is the only insect control practiced.

The farm is surrounded by other agricultural land and is located southeast of the city of Bakersfield, approximately two miles from the nearest residences. This separation is sufficient to prevent nuisance odors and insects from disturbing local citizens.

Cotton is the only cash crop grown. Corn, barley, alfalfa, wheat and permanent pasture are used for animal feed on the farm. Irrigation with primary effluent is restricted by the California State Health Department to crops not for human consumption.

The reclaimed water supply must be augmented during the months of June, July, and August by well water which constitutes 33 percent of the total supply during these summer months.

In Bakersfield's experience, the effect of using reclaimed primary effluent varies with the crop. Corn and permanent pasture is reported to grow equally well using fresh water irrigation systems or using primary effluent. The grain crops of alfalfa, barley, and wheat also showed growth and yields comparable to crops irrigated with fresh irrigation water. Bakersfield reports, however, that high nitrogen concentrations in the reclaimed water can impair optimum production of grain crops, and careful management is necessary to regulate the amount of irrigation water used and the amount of nitrogen assimilated by the plants. Cotton is the only crop that appeared to be detrimentally affected by irrigation with primary effluent. The high concentrations of nutrients direct growth to the plant rather than to the cotton boles; thus, cotton production is reduced by an estimated 25 percent compared to irrigation with fresh water and balanced fertilization.

Substantial storage capacity is important for an optimum irrigation program with reclaimed wastewater. The present irrigation program at Bakersfield is impaired by inadequate lagoon storage capacity which prevents complete satisfaction of high summer demands and forces overuse in the rainy winter season, causing saturation of the fields and ponding. A proposed reservoir of 800 to 1,500 acre-ft would balance the reclaimed water supply to meet seasonal needs. Also planned is increased replacement of open earth ditches with irrigation pipe in order to increase percolation and reduce tailwater accumulation, storage, and pumping.

The city recognizes the potential for groundwater contamination when irrigating with primary effluent. The major concern is that nitrates will increase in groundwater and well supplies. Studies are presently under way to determine the effects of reclaimed water irrigation on groundwater quality in the area. Preliminary investigations indicate no nitrate contamination of well water supplies has occurred during the first 50 years of the Bakersfield reclamation operation.

ECONOMICS

The city of Bakersfield realizes substantial savings because primary treatment is sufficient for disposal to field irrigation whereas secondary treatment would be required if the effluent was discharged to surface waters. The approximate 1972 cost for primary treatment is \$113/MG at Plant No. 1, and \$92/MG at Plant No. 2. The city estimates an increase to \$175/MG if secondary treatment were necessary (costs include capital amortization).

Financial savings through the use of the reclaimed water are significant for the farming and livestock operation also. No exact dollar values are available, but the farm operator believes a savings of \$5/acre annually in water cost is conservative. A greater savings would be possible if the effluent were properly balanced to meet all seasonal demands. Construction of deep wells has been necessary to augment the flow from the treatment plants in the summer. The \$9,000/year cost for mosquito abatement could also be reduced by proper water storage and balancing to reduce tailwater volume and ponding on the fields.

BURBANK, CALIFORNIA

INTRODUCTION

Located in the heart of the downtown area, the municipal wastewater reclamation facility at Burbank attains a significantly higher quality effluent than is typical of conventional secondary treatment systems. Since 1967, the city power generating plant has successfully utilized this effluent for cooling water makeup. Initial problems with effluent reuse were solved by close cooperation between personnel of the wastewater treatment plant and the power plant. Cooperation continues on a day-to-day basis to ensure optimum operation. In the opinion of SCS Engineers, the Burbank reclamation operation is presently among the outstanding examples of cooling makeup water reuse in the nation.

MUNICIPAL TREATMENT PROCESSES

The municipality treats an average raw sewage flow of 5.2 mgd, ranging from 2 to 9 mgd. The influent contains approximately 25 percent industrial waste, predominantly generated by aircraft manufacture and containing hexavalent chromium, cyanide, and heavy metals. Concentrations of undesirable industrial waste characteristics are controlled by a ridgidly enforced industrial waste ordinance and frequent inspections.

The 6 mgd design capacity treatment plant, as diagrammed in Figure A-5, includes screening and barminutors, followed by gravity settling in two rectangular primary clarification tanks designed for 1,250 gpd/sq ft surface overflow rate. The three aeration tanks are each 30 ft wide by 210 ft long by 15 ft deep. The tanks may be operated in parallel or in series. Presently, series operation is used with step feed of the primary effluent at 10 ft, 60 ft, 110 ft, and 160 ft from the beginning of the first tank. Design parameters for the aeration tanks include the following:

- BOD load - 31 lbs/1,000 cu ft tank volume
- Air supply - 1,300 cu ft/lb BOD removed or 1.9 cu ft/gal
- Detention period - 8.4 hrs

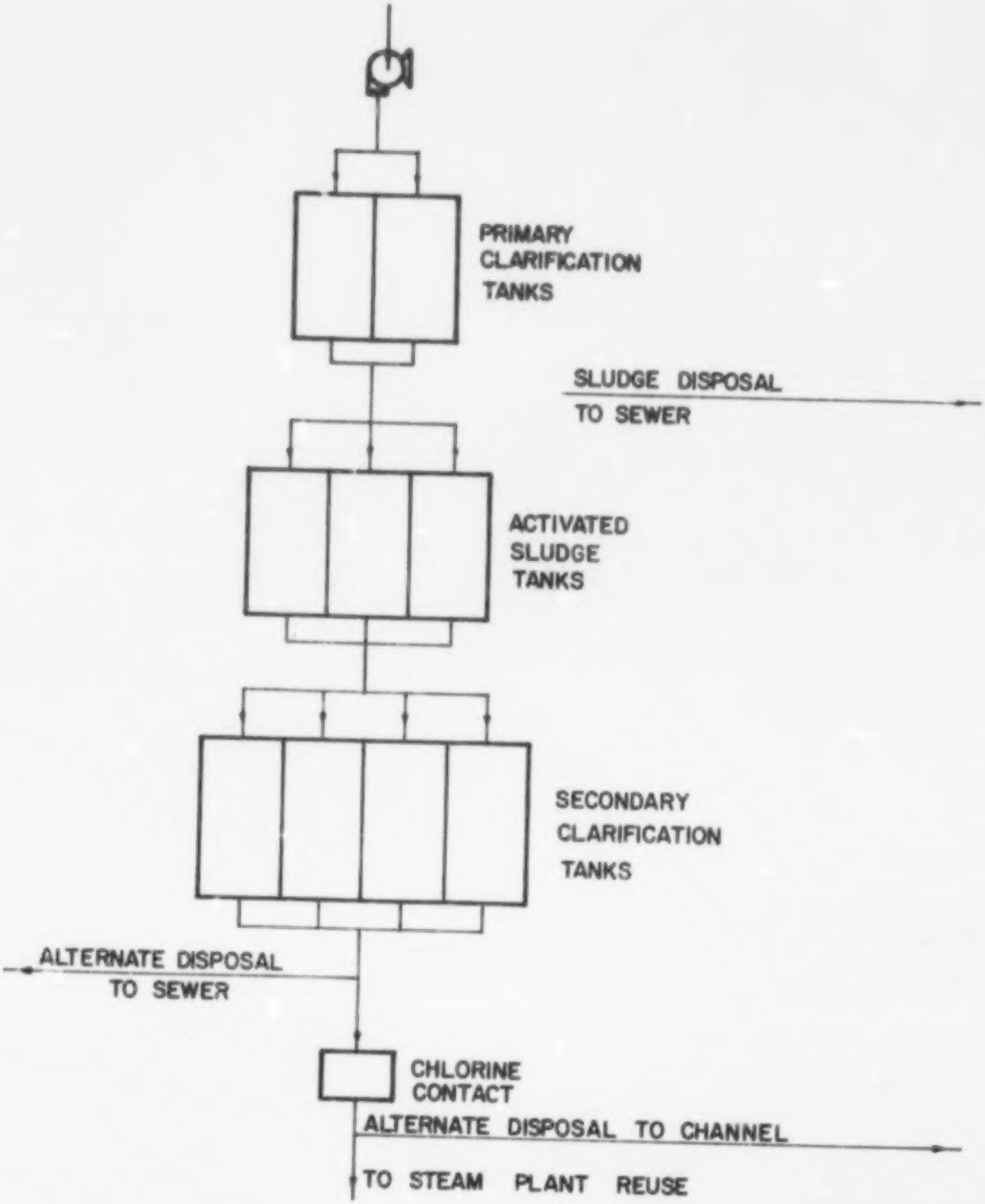
PRIMARY
CLARIFICATION
TANKS
SLUDGE DISPOSAL
TO SEWER
ACTIVATED
SLUDGE
TANKS
SECONDARY
CLARIFICATION
TANKS
ALTERNATE DISPOSAL
TO SEWER
CHLORINE
CONTACT
ALTERNATE DISPOSAL TO CHANNEL
TO STEAM PLANT REUSE

FIGURE A-5
MUNICIPAL WASTE WATER TREATMENT FACILITY
BURBANK, CALIFORNIA

- Return sludge - 30 to 70 percent.

Present operation utilizes one of the aeration tanks for sludge reaeration, maintains approximately 900 mg/l MLSS in the aeration tanks, and recirculates approximately 30 percent return activated sludge.

Final clarification is provided by four rectangular clarifiers designed for 935 gpd/sq ft overflow rate.

The final treatment step is chlorination at a dosage of approximately 7 mg/l for 45 minutes producing a residual of 2 to 3 mg/l. Typical plant effluent quality is shown in Table A-5. It should be noted that the city of Burbank plant has a significant advantage over other plants because it disposes of its raw sludge to the city of Los Angeles via a nearby interceptor sewer. No sludge and supernatant handling requirements are a great asset in producing an exceptional quality effluent. In case of an emergency, the same interceptor to the city of Los Angeles can be used to dispose of raw sewage or poor effluent.

Table A-5. AVERAGE MUNICIPAL EFFLUENT CHARACTERISTICS AT BURBANK

Characteristic	Concentration (mg/l)	Characteristic	Concentration (mg/l)
BOD	0.66	Organic N	39
SS	4.5	Pb	0.01
TDS	500	Cr	0.02
Na	88	Zn	0.02
Cl	82	Ne	0.32
pH	7.2	Cu	0.03
MPN	0-20	B	0.9
Total Hardness	160	Hg	0.002
Total PO_4	20	Cd	0.002

Water not used for cooling water makeup is discharged to the Los Angeles River and ultimately used for groundwater recharge via spreading grounds.

The power plant has no specific limitation on the effluent quality received; however, minimum levels of dissolved and suspended solids, phosphate, nitrogen, and organics are desired. The power plant cannot discharge wastewater with greater than 750 mg/l TDS, thus severly limiting the number of recycles of water prior to blowdown.

Communication between treatment plant personnel and power plant personnel is important in the success of the effluent reuse practice in Burbank. Any change in effluent characteristics or performance of the reused water in the cooling towers is immediately reported and discussed.

REUSE PRACTICES

The city of Burbank's 170 Mw power generation station uses approximately 2 mgd of the renovated water in its mechanical draft cooling towers. This volume varies from 1.5 to 2.5 mgd with about 25 percent more water used during the summer months when high power demands are placed on the station.

User treatment includes shock chlorination once daily in winter and twice daily in summer to produce a 1 mg/l chlorine residual. The pH is adjusted to between 6.6 and 6.8 with sulfuric acid. Poly-electrolyte is added for corrosion inhibition and scaling prevention. All chemical additions are direct to the recirculating cooling water.

Standby supplies from the city potable water sources are available if required. Prior to implementation of the wastewater reuse, the city water supply was the only source of makeup water, and the power plant has good data comparing the treatment required for effluent vs. potable city water. Effluent generally is reported to have the following disadvantages:

1. Greater chlorine dosage is needed to prevent growths due to the nutrient values. The difference is approximately 2:1 in the winter and 4:1 in the summer.

2. More acid for pH control is required because of the greater buffering action. The difference is approximately 3:2.

3. More poly-electrolyte is required.

4. More water is required in the cooling operation because the higher TDS of the wastewater prevents as many recycles as could be obtained with potable water.

ECONOMICS

Municipal waste treatment costs are estimated at $126/MG, based upon the following reported costs: labor, $74,000; supplies, $13,000; utilities, $27,000; and other items, $4,000. Capital cost of the treatment plant was $1.1

million in 1966 which represents an equivalent 1972 cost of $1,626,000 calculated with the FWPCA Sewage Treatment Plant Construction Cost Index Ratio (1972/1966 = 1.48). Therefore, annual capital amortization (5.5% over 25 years) totaled $121,367. Adding the operating costs to amortization yielded a total annual treatment cost of $239,367 or $126/mg for the annual effluent volume of 1,898 mg. Reclaimed water sales, though simply an inter-city transfer, totaled $31,000 in 1972 at a rate of $43/MG.

It is estimated by SCS Engineers that the power plant spends approximately $100/MG for additional chemical treatment as previously described. The combined cost of $226 compares very favorably with total costs reported by other municipalities, and is a strong argument for the overall efficiency of the Burbank reclamation program.

CALABASAS, CALIFORNIA

(LAS VIRGENES MUNICIPAL WATER DISTRICT)

INTRODUCTION

The Las Virgenes Water District has been reclaiming treated effluent since 1965. Currently, it is using renovated water for crop and pasture irrigation. However, a $3.5 million expansion of the reclaimed water system is tentatively planned for 1976 and is to include a series of recreational lakes as well as an enlarged irrigation program. The reclamation plant was selected Los Angeles Basin Plant of the Year for 1972 and is an outstanding example of good activated sludge design and operation.

MUNICIPAL TREATMENT PROCESSES

The Tapia Treatment Plant in Las Virgenes gives secondary treatment to an average wastewater flow of 3 mgd, 10 percent of which is contributed by industry. However, all industries are required to pretreat their waste to domestic sewage strengths, and no heavy metal concentrations are allowed in excess of USPHS Drinking Water Standards. Due to these stringent discharge controls, no problems are experienced at the treatment plant due to industrial wastewater flows.

Figure A-6 shows a schematic flow diagram of the treatment processes. Primary treatment consists of comminution followed by sedimentation in two rectangular tanks each 125 ft x 20 ft x 12 ft in dimension, with a 1,600 gpd/sq ft overflow rate, and 1.1 hour detention time at the design flow rate of 8 mgd.

The wastewater then enters three rectangular activated sludge aeration tanks, each having dimensions of 160 ft x 30 ft x 15 ft. The operation is step feed with 3.6 hour detention at a sludge recirculation rate of 33 percent. Air is diffused at 1 cu ft per gallon of raw sewage or approximately 1,000 cu ft of air per lb of BOD removed. The MLSS concentration is regulated with seasonal temperature and microbiological activity to 1,600 mg/l in the summer and

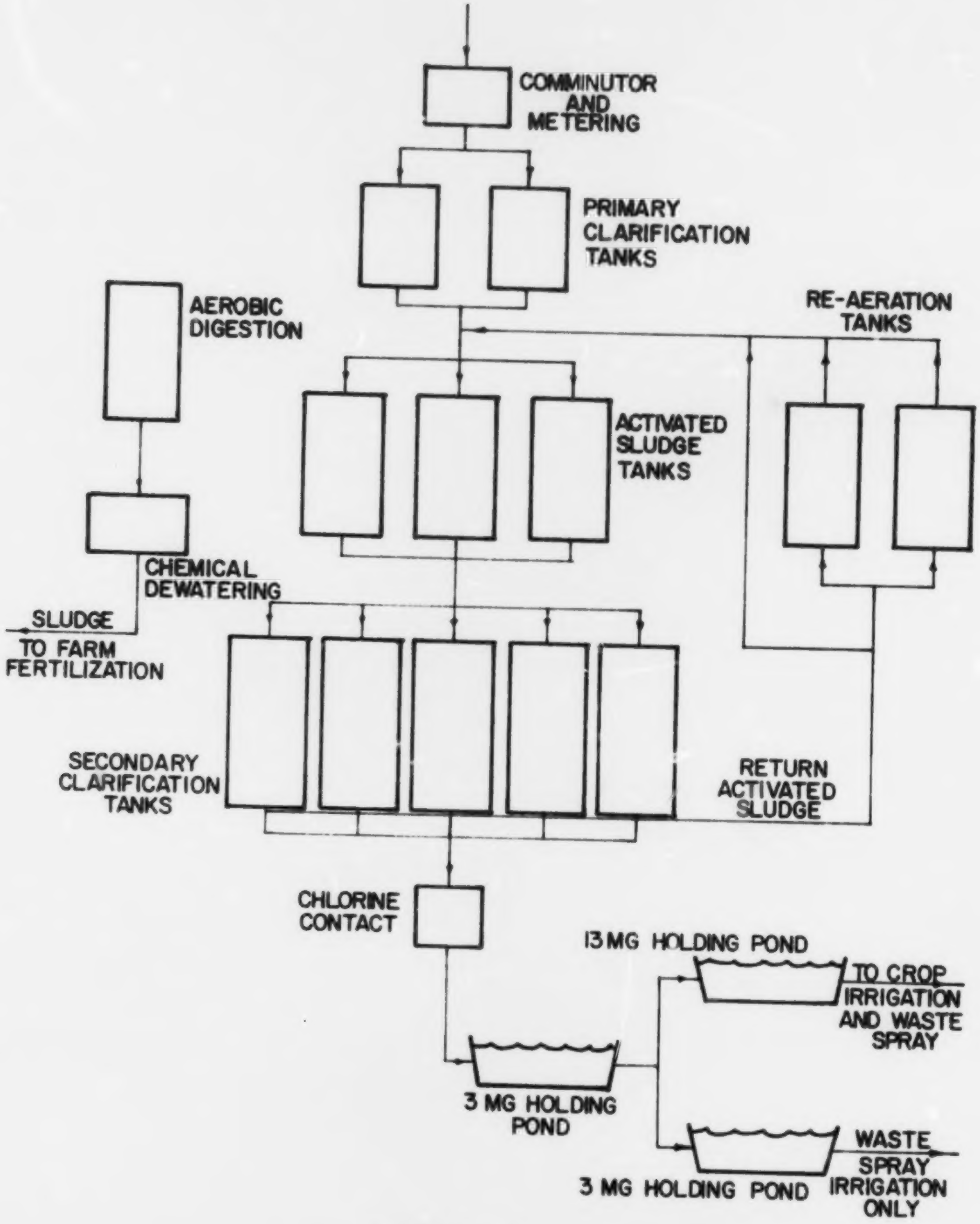
COMMINUTOR AND METERING
PRIMARY CLARIFICATION TANKS
AEROBIC DIGESTION
RE-AERATION TANKS
ACTIVATED SLUDGE TANKS
CHEMICAL DEWATERING
SLUDGE
TO FARM FERTILIZATION
SECONDARY CLARIFICATION TANKS
RETURN ACTIVATED SLUDGE
CHLORINE CONTACT
13 MG HOLDING POND
TO CROP IRRIGATION AND WASTE SPRAY
3 MG HOLDING POND
3 MG HOLDING POND
WASTE SPRAY IRRIGATION ONLY

FIGURE A-6
MUNICIPAL WASTE WATER TREATMENT FACILITY
TAPIA PLANT
LAS VIRGENES, CALIFORNIA

2,600 mg/l in the winter. The activated sludge process is closely monitored and regulated to achieve consistent complete nitrification. Concentration of nitrate nitrogen (NO_3) is monitored at regular intervals along the aeration tanks with corrections and modifications of the operation geared to maintain proper concentration and activity of the sensitive nitrifying bacteria (Nitrosomonas and Nitrobacter).

Following aeration, the mixed liquor is settled in five secondary clarification tanks each 150 ft x 20 ft x 10 ft in dimension, with a 600 gpd/sq ft overflow rate, and 2.5 hour detention time at design flow. Presently, one of the secondary clarifiers is being used as a chlorine contact chamber to supplement the old chlorine tank and provide 1.1 hours of contact time. A chlorine dosage of 8 mg/l results in a free chlorine residual of 1 mg/l.

Return activated sludge can be reaerated prior to return to the aeration tanks. A combination of settled waste activated sludge and primary sludge is pumped into two aerobic digestion tanks with 120 ft x 30 ft x 15 ft dimensions, which provide 20 days of detention time at a total plant flow rate of 4 mgd. Digested sludge is dewatered in three dual cell gravity units and trucked to agricultural fields for spreading and tilling into the soil.

Following chlorination, the final effluent is stored in a 3 MG asphalt lined reservoir. From the here the reclaimed water is pumped to two unlined stabilization/storage reservoirs. The first reservoir holds 3 MG and contains only excess water for waste spray disposal on non-productive land. During winter months, all effluent is disposed in this manner since the Tapia plant has no permit for stream discharge, except during periods of inclement weather. The second reservoir holds 13 MG of reclaimed water for crop and permanent pasture irrigation. Gravity feed from the reservoirs supplies sufficient head for irrigation and disposal operations.

As summarized in Table A-6, the final effluent from the Tapia plant approaches drinking water quality. BOD, SS, heavy metal concentrations, and Coliform MPN are very low. The low metals concentrations are due to the stringent industrial discharge regulations.

REUSE PRACTICES

Reclaimed wastewater is currently used for irrigation of nearby farmland. The irrigation program is highly seasonal utilizing approximately 60 percent of the total effluent flow from March to October, and little water the remainder

Table A-6. AVERAGE MUNICIPAL EFFLUENT CHARACTERISTICS AT LAS VIRGENES

Constituent	Concentration (mg/l)	Constituent	Concentration (mg/l)
Pb	0.022	B	0.77
Cd	0.003	NO_3-N	13.2
Cu	0.014	NO_2-N	0.07
Ni	0.031	NH_3-N	0.0
Zn	0.056	Cl	112
MBAS	0.34	TDS	870
CRTG	0.0	SO_4	267
Phenols	0.034	PO_4	32.8
Org-N	2.2	BOD	3
F	0.36	SS	1
pH	7.8	MPN	2.2

of the year. The following crops and acreages are irrigated:

- Alfalfa - 225 acres
- Permanent pasture - 30 acres
- Sudan grass - 5 acres

In addition, the campuses of a local grade school and Pepperdine University (Malibu) are irrigated with effluent during the summer months.

The irrigation system will be expanded next year to include a golf course and green belt areas in the community of Calabasas. The additional demand will be for 300 to 500 acre-ft/year of reclaimed water.

As seen in Table A-6, the nutrient concentrations in the renovated effluent are quite high, due in part to the complete nitrification aeration process. The nutrient value in the effluent is estimated at approximately $18/acre-ft based on current market values for nitrogen and phosphorus fertilizers.

Farmers have reported favorable results using effluent water. Yields of alfalfa have increased over previous years when well water was used. Some of this alfalfa is used to make "alfalfa juice concentrate", a health food supplement for human consumption. The final product of dehydrated alfalfa juice has successfully passed all FDA requirements and is sold on the open market. The growth of sudan grass has been markedly stimulated by irrigation with reclaimed water; used as green feed for cattle, the best previous production using well water was one regrowth after harvest. Currently, three regrowths occur each season approximately doubling gross production.

The treated effluent is of such high quality that no significant problems are reported with the irrigation program. Soil damaging constituents are not evident and suspended solids are so low that no plugging of spray nozzles has occurred.

The water district is planning a $3.5 million expansion of the reclaimed water system in 1976. In addition to enlarging the irrigation program several recreational lakes will be constructed for public fishing and picnicking.

Extensive bio-assay experiments are being conducted in the plant laboratory to determine acute and long-term toxic effects of the effluent on fat-head minnows and gambusia (mosquito fish). The purpose of the experimentation is two-fold: (1) to assure the success of fish health, reproduction, and growth in planned reclaimed water recreational lakes; and (2) to validate requests for a stream discharge permit by proving that the plant effluent has no deleterious effects on fish life.

Preliminary results have been encouraging as no toxic effects have been observed either in the lab aquariums or the two treatment plant aeration tanks presently used as fish raising reservoirs. Reproduction and vital activities have been normal.

Fish have also been introduced into the existing reclaimed water reservoirs. Bass, bluegill, crappie, and catfish have shown higher growth rates (bass growing from 4 inches to 16 inches in 15 months) and equivalent reproductive activities than are reported for identical species living in natural surface waters.

ECONOMICS

The Las Virgenes Municipal Water District sells reclaimed water to the farmers for $15/acre-ft. The price was selected to be competitive with the cost of local well water, which is of poor quality with TDS concentrations of 1,300 to 1,500 mg/l. Because of the added nutrient value and competitive cost of the high quality effluent supply, the farmers have switched to 100 percent reclaimed water usage with well water used only as standby.

The $15/acre-ft amortizes the reclaimed water piping system; thus, the municipal water district is reimbursed for a minor portion of their estimated treatment costs of $348/MG while the farmers receive high quality water at costs competitive with poor quality well water supplies.

SANITATION DISTRICTS OF LOS ANGELES COUNTY (LANCASTER, CALIFORNIA)

INTRODUCTION

Since 1971, the Sanitation Districts of Los Angeles County have sold renovated wastewater to the county of Los Angeles for use in a chain of three recreational lakes. The lakes have a capacity of 80 MG and serve as a focal point for the Counties' 56 acre Appolo Park. The park, located near Lancaster, California, was opened to the public in 1973 and features sport fishing, boating, picnic areas, play fields, hiking, and camping. Pending final tests, the fish caught are not kept for eating. The area has a typical southwest desert climate.

During 1973, an average of 0.5 mgd of renovated wastewater for the Appolo Park lakes was supplied by the District's Renovation Plant No. 14 near Lancaster, California. The treatment, which is simple and relatively inexpensive, was developed through an extensive research and pilot program conducted by the District and the federal EPA to establish design criteria for the project. This background data, and the operating experience now being developed, will be of value to future similar recreational lake developments.

MUNICIPAL TREATMENT PROCESSES

The District Wastewater Renovation Plant No. 14 near Lancaster provides oxidation pond treatment to an average influent flow of 4 mgd. An average of 0.5 mgd of the pond effluent is filtered and chlorinated prior to pumping to the recreational lakes. Figure A-7 on the following page shows a schematic flow diagram of the operation.

The raw influent passes through a communitor and into two primary sedimentation tanks. Only 5 percent of the raw sewage flow is contributed by industry and no deleterious effects on plant operation are reported.

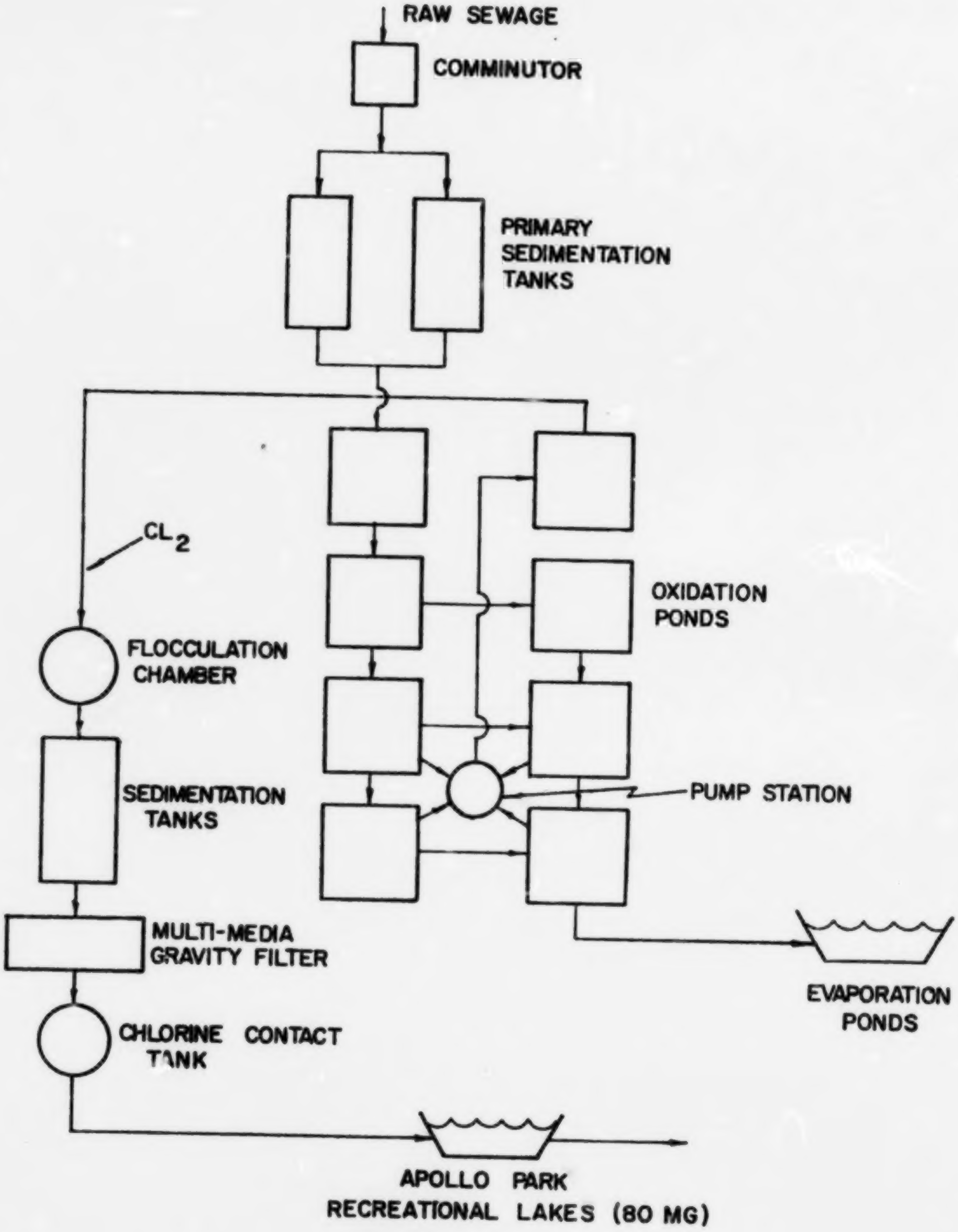
RAW SEWAGE
COMMINUTOR
PRIMARY SEDIMENTATION TANKS
CL$_2$
OXIDATION PONDS
FLOCCULATION CHAMBER
SEDIMENTATION TANKS
PUMP STATION
MULTI-MEDIA GRAVITY FILTER
EVAPORATION PONDS
CHLORINE CONTACT TANK
APOLLO PARK
RECREATIONAL LAKES (80 MG)

FIGURE A-7
WASTEWATER RENNOVATION PLANT NO. 14
(LANCASTER) LA COUNTY SANITATION DISTRICT

Secondary treatment is provided by eight oxidation ponds, with a total surface area of 240 acres. Detention at average flow rates is 60 days with a BOD loading of 100 lbs/acre/day. An average of 3.5 mgd of effluent from the oxidation ponds is retained behind dikes for disposal by evaporation. The remaining 0.5 mgd is given the following sequence of tertiary treatment stages:

- Flocculation
- Sedimentation
- Filtration
- Chlorination,

for removal of phosphates, suspended solids, algae, and bacteria.

Effective flocculation is achieved with an average alum dosage of 300 mg/l. The flocculation chamber is designed for 380 gpm, with tank dimensions of 16 ft x 8 ft x 8 ft depth and a detention time of 20 minutes.

Sedimentation is provided by a covered tank measuring 16 ft x 68 ft x 7 ft depth. Two and one half hours of retention time is provided at an overflow rate of 500 gpd/sq ft.

Following sedimentation, a multi-media filter is employed for further solids removal.

Characteristics of the unit are as follows:

- Filter media - 18 in. anthrafilt
  9 in. sand
  15 in. gravel
- 360 gpm design flow
- 180 sq ft filter bed area
- 2.0 gpm/sq ft loading rate
- 7.0 ft final head loss
- 18 gpm/sq ft max. backwash rate
- 2.0 gpm/sq ft surface wash at 50 psi
- 50 percent bed expansion

Following filtration, chlorination is accomplished in a contact tank with 44,000 cu ft volume and 8 hour detention time. Chlorine dosage will range up to 15 mg/l to provide the desired 3.4 mg/l residual in the recreational lake supply.

Problems experienced to date include high turbidity and ammonia levels during winter months, as cooler temperatures cause slowing of biological activity in the oxidation ponds. In order to affect complete nitrification and breakdown of ammonia, long retention periods (60 days in the summer and longer periods in the winter) are provided in the secondary oxidation ponds. An undesirable side effect, however, is that the TDS concentrations of the ponds increase with time due to high evaporative loss. The tertiary treatment plant has no significant effect on dissolved solids. Thus, the high TDS concentrations are passed on to the recreational lakes. Evaporation in the recreational lakes further concentrates the dissolved solids, often to levels as high as 1,200 mg/l.

To alleviate the situation, low ammonia water is stored each autumn in one of the oxidation ponds for release during the winter to dilute water with higher ammonia concentration as necessary. In addition, irrigation with lake water is encouraged to keep water flowing through the lakes and to control increasing TDS concentrations.

Table A-7 on the following page shows effluent qualities for the oxidation ponds and the tertiary plant. Quality requirements for the tertiary effluent are also listed. General requirements for the reclaimed water for recreational use are set by the State as follows:

"It is desirable that the reclaimed water be of high quality, low in dissolved salts and nutrients, while fully oxygenated. The water must be pleasing esthetically, in both clarity and odor for full public acceptance. It must be capable of sustaining fish life and of course be pathogenically acceptable."

REUSE OPERATIONS

The tertiary effluent at Lancaster is used as the sole source of makeup water for three recreational lakes for use by boaters and fishermen. Discharge from the lake is utilized for irrigation of park landscape and leaching operations to reclaim nearby alkaline soils.

Water is not supplied to the aquatic park unless it meets all the quality standards delineated in Table A-7. To insure compliance, turbidity, phosphate, chlorine, and ammonia tests are made daily; alkalinity and suspended solids tests are run weekly; and tests for all other constituents are carried out every two weeks.

Water quality characteristics of the recreational lake water are summarized in Table A-8.

Note the high TDS concentrations as previously mentioned. However, as the other characteristics show, the reclaimed lake water is of good overall quality.

Table A-7. LANCASTER, CALIFORNIA, RENOVATION PLANT NO. 14 WATER QUALITY CHARACTERISTICS AND REQUIREMENTS

Constitutents	Oxidation Pond Effluent (Dec. 1971)	Tertiary Effluent (Dec. 1971)	Lake Supply Quality Requirements
Turbidity (JTU)	23.0	1.5	3-10
PO_4^{-3} (mg/l)	29.0	0.25	0.1-0.5
pH	9.15	6.15	6.5-7.0
BOD (ppm)	5.8	0.4	5-10
COD (ppm)	149.0	35.0	45-75
DO (ppm)	12.4	12.4	7-15
Algae Counts	200,000	--	--
Coliform (MPN)	150,000	--	0-2.2
Temp. (°C)	34.0	38.0	10-30
SS (ppm)	25.0	5.0	10
TDS (ppm)	560.0	544.0	500-650
NH_3-N (ppm)	1.1	1.0	0.1-15.0
Org. N (ppm)	8.6	1.7	1.0-3.0
NO_3-N (ppm)	1.8	1.9	1.0-4.0
Total N (ppm)	--	--	3-20
Total Alk (ppm)	227.0	65.0	74-140
Hardness (ppm)	69.0	68.0	85-110
Boron (ppm)	1.06	0.74	0.8-1.4
Na (ppm)	--	153.0	--
Residual Cl_2 (ppm)	--	3.4	0.5-2.5
CO_2 (ppm)	--	68.0	1
ABS (ppm)	0.1	0.0	7-15
Fl^- (ppm)	--	1.7	--
Ca^{++} (ppm)	--	61.0	--
Cl^- (ppm)	--	85.0	--
$SO_4^=$ (ppm)	--	65.0	--
Total heavy metals (ppm)	--	0.53	--

Table A-8. ANTELOPE VALLEY WATER RECLAMATION PROJECT RECREATIONAL LAKES QUALITY

	Lake No. 1	Lake No. 2	Lake No. 3
Temperature, ^{o}F	35	37	36
Turbidity, JTU	21	20	25
pH	7.6	8.58	8.62
Total Dissolved Solids, mg/l	833	932	853
Suspended Solids, mg/l	26	32	9
Alkalinity, mg/l $CaCO_3$	143	168	151
Boron, mg/l B	1.27	1.48	1.26
Carbon Dioxide, mg/l CO_2	3.17	0	0
Chlorine Demand/hr, mg/l Cl	0.89	0.94	1.09
Chlorine Residual, mg/l Cl	0	0	0
Total Hardness, mg/l $CaCO_3$	116	128	120
MBAS, mg/l ABS	0.1	0.1	0.1
Ammonia Nitrogen, mg/l N	1.0	1.3	1.4
Organic Nitrogen, mg/l N	2.2	2.1	1.8
Nitrite Nitrogen, mg/l N	0.01	0.03	0.03
Nitrate Nitrogen, mg/l N	1.3	0.6	1.2
BOD, mg/l 0	0.9	1.2	1.7
Total COD, mg/l 0	44	51	47
Dissolved Oxygen, mg/l 0	10.7	11.8	12.2
Ortho Phosphate, mg/l PO_4	0.26	0.26	0.20
Total Phosphate, mg/l PO_4	0.37	0.41	0.39
Potassium, mg/l K	19	19	18
Sodium, mg/l Na	235	268	235
Sodium Equivalent Ratio, %Na	78.5	79.3	78.2

A program of fish stocking was initiated in the spring of 1971. Table A-9 below summarizes past and future fish planting operations.

Table A-9. APOLLO PARK FISH STOCKING PROGRAM

Date	Type	Number	Size
December, 1971	Rainbow trout	100	4-6"
March, 1971	Large mouth bass	100	Mature
	Redear sunfish	50	Mature
	Channel catfish	20	Mature
	Gambusia	1,000	Mature
March, 1973	Channel catfish	5,200	4-6"
Future program annually	Rainbow trout	40,000	1/2 lb
	Channel catfish	10,000	1/2 lb

Fish growth in the recreational lakes has been extremely good to date, averaging roughly 1" per month. Some of the trout planted in December, 1971 measured from 18"-24" when caught two years later. Observations have shown all fish metabolism and reproduction to be normal and lab analyses have failed to reveal any bacteriological or virological disease.

It is anticipated that the lakes will be opened to the public for fishing in 1974 pending final verification of the epidemiological quality of the fish.

ECONOMICS

The county of Los Angeles pays the L.A. Sanitation District approximately $30,000 per year for the reclaimed wastewater used in the recreational lakes. This sum reimburses the Sanitation District for operation and maintenance of the tertiary portion of the treatment plant.

It is estimated that the total cost (present worth) of the Apollo Park project is $5,777,050 which includes a construction cost of $2,415,150 and operation, maintenance, and part replacement present worth of $3,361,900 (capitalized at 4 percent for 50 years).

Recreational benefits are estimated at $1.60 per visitor day based on the "Recreation and Fishing and Wildlife Enhancement Benefits," prepared by the State Department of Water

Resources. Total recreational benefit present worth is calculated as $16,431,600, yielding a "benefit-cost ratio" of 2.8:1.

Costs of maintaining the fishing program are not available as yet. However, it is anticipated that in the future a $1.00 facility permit fee per fisherman per day may be required to help finance the fish stocking program. The lake and fish population is large enough to accomodate 20,000 fishermen per year. Thus, the permit program could raise roughly $20,000 per year in revenue.

SAN BERNARDINO, CALIFORNIA

INTRODUCTION

The city of San Bernardino, California has supplied reclaimed water since 1960 to the State Division of Highways for freeway landscape irrigation purposes. The lush landscaping totals approximately 80 acres under irrigation, and enhances approximately 3 miles of 8 lane freeway with a wide variety of trees, shrubs, and groundcover.

The effluent receives tertiary treatment including lime treatment, gravity sand filtration, and chlorination prior to reuse. This is the only significant example of reuse for highway landscaping in the nation and provide background information for others contemplating similar applications.

MUNICIPAL TREATMENT PROCESSES

The treatment plant processes 16 MG of water a day of which 3 mgd is given tertiary treatment for reuse. The raw sewage is approximately 15 percent industrial, however,it causes no significant effect upon the characteristics of the plant influent. At the time this report was prepared, the city plant was undergoing a major expansion and we will describe the treatment processes only briefly.

Primary treatment consists of screening followed by gravity settling in covered circular clarifiers of 120 ft diameter. The primary clarification tanks are kept under a slight vacuum and are equipped with $KMnO_4$ spray units for odor control.

Secondary treatment is conventional activated sludge followed by secondary clarification and chlorination. Because the plant is in the midst of an expansion program, design details and performance are not meaningful to this report. Sludge handling involves thickening, digestion with sludge heating, separation by centrifuge, and fluidized bed incineration at 400 deg F and 300 psi.

Thirteen mgd not receiving tertiary treatment is discharged to the Santa Ana River. Tertiary treatment as shown in

Figure A-8 is installed to process the remaining 3 mgd for reuse as irrigation water. Secondary effluent from the chlorination tank flows through a 10 mesh revolving screen and into a 60 ft diameter reaction clarifier with a 16 ft depth and 2,100 gpm overflow rate. Lime, alum and polymer are added to effect coagulation and $KMnO_4$ is added for odor removal. Mixing, coagulation, floculation, internal recirculation and clarification take place in the reaction clarifier. The reactor clarifier chemicals are added by a dry lime feeder, liquid alum pumps and liquid polymer pumps.

Reactor effluent is filtered through a 3 cell circular gravity sand filter of 32 ft diameter and 10 ft deep.

The filter backwashes itself automatically as required using previously filtered water in storage. Backwash wastewater is returned to the primary clarifier of the sewage treatment plant. Following filtration, the renovated effluent is heavily chlorinated and stored in a 1 MG asphalt-lined holding pond. Pumps withdraw water from the lagoon to feed two pressure tank systems, one of 700 gpm capacity supplying a local golf course, and a second of 500 gpm capacity at 150 psi pressure to supply 3 miles of freeway landscaping.

Table A-10 shows typical quality characteristics of the effluent after tertiary treatment.

Table A-10. AVERAGE TERTIARY EFFLUENT CHARACTERISTICS AT SAN BERNARDINO, CALIFORNIA

Characteristic	Concentration (mg/1)
BOD	13
SS	-
TDS	553
Na	85
Cl	83
pH	7.4
MPN	2

REUSE PRACTICES

In 1972, the reclaimed tertiary treated water was used to irrigate fairways and greens of the Orange Show Public Golf Course and a 3 mile section of freeway landscaping on Interstate 15 through San Bernardino. Golf course irrigation consumes 1 mgd of reclaimed water in the drier summer

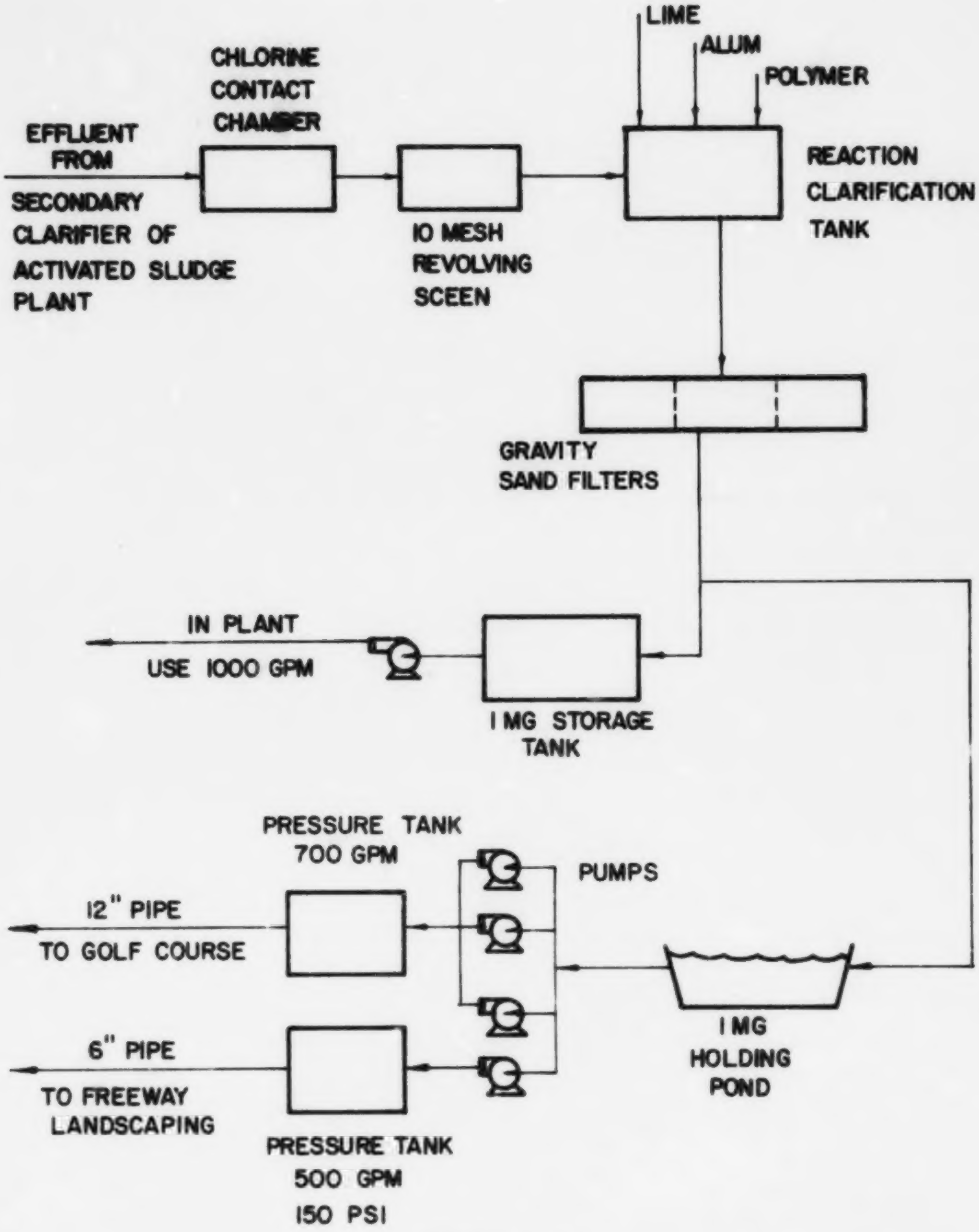
LIME
ALUM
POLYMER
CHLORINE CONTACT CHAMBER
EFFLUENT FROM
SECONDARY CLARIFIER OF ACTIVATED SLUDGE PLANT
10 MESH REVOLVING SCEEN
REACTION CLARIFICATION TANK
GRAVITY SAND FILTERS
IN PLANT
USE 1000 GPM
1 MG STORAGE TANK
PRESSURE TANK 700 GPM
PUMPS
12" PIPE
TO GOLF COURSE
1 MG HOLDING POND
6" PIPE
TO FREEWAY LANDSCAPING
PRESSURE TANK 500 GPM 150 PSI

FIGURE A-8
TERTIARY SYSTEM
MUNICIPAL WASTEWATER TREATMENT FACILITY
SAN BERNARDINO, CALIFORNIA

months and 0.5 mgd during winter. Approximately 2 mgd of effluent from the municipal plant is used to irrigate the freeway landscape. A large variety of plants are grown along this section of freeway and the Division of Highways reports no problems associated with use of the reclaimed water. Types of plants grown are:

Nerium oleander	Common Oleander
Parthenocissus tricuspidata	Boston Ivy
Pyracantha Santa Cruz	Fire-Thorn
Lagerstroemia indica	Crape Myrthe
Platanus racemosa	California Sycamore
Schinus molle	California Pepper Tree
Photina arbutifilia	Toyon
Punica granatus	Pomegranate
Washingtonia robusta	Mexican Fan Palm
Baccharis pilularis	Dwarf Coyote Brush

ECONOMICS

In 1971, the city of San Bernardino realized a revenue of $3,500 from the sale of reclaimed water to the Orange Show Golf Course, at a price of $15.34/MG. Reclaimed water was given free of charge to the highway department for landscape irrigation and thus no revenue was generated from the water use.

The treatment costs, as calculated by SCS Engineers, amount to $355/MG with capital amortization, and $100/MG without amortization.

COLORADO SPRINGS, COLORADO

INTRODUCTION

The city of Colorado Springs currently provides tertiary treatment to a portion of its secondary effluent for reuse in irrigation and cooling tower makeup. Their experience is of great interest to others contemplating reuse because the secondary treatment plant effluent is of relatively poor quality and tertiary treatment includes chemical clarification, dual media filtration, and carbon adsorption. Of the 20 mgd of sewage given secondary treatment at the plant, approximately 5 mgd receives tertiary filtration and is piped throughout the city in a non-potable water distribution system to provide irrigation water for city facilities. An additional 2 mgd is given chemical clarification and carbon adsorption tertiary treatment for supply to the municipal power generation plant for cooling water makeup. A new 30 mgd activated sludge plant, due to be completed in mid 1973, will replace the existing trickling filter plant.

MUNICIPAL TREATMENT PROCESSES

The treatment plant treats an average daily flow of 19 mgd in the winter and 23 mgd during summer months. Approximately 10 percent of this flow is industrial wastewater, primarily from electronics manufacturing and metal plating operations. Most significant contaminants in raw sewage are copper (1 to 1.5 mg/l), hexavalent chrome (0.3 mg/l), and zinc (1.0 mg/l).

Figure A-9 illustrates the unit processes of the present plant. Raw sewage is degritted followed by comminution and flow measurement. A splitter box diverts the wastewater to three primary clarifiers, each 115 ft in diameter and having a detention time (with recirculation) of about 2 hours at maximum flow. A 122,500 gal primary effluent storage tank feeds a constant rate to the trickling filters. Pumps transfer the water from the storage tank to a distribution tower where a steady head is maintained to the trickling filter units. The three trickling filters are each 170 ft in diameter with a bed depth of 5 1/2 ft. The filter media

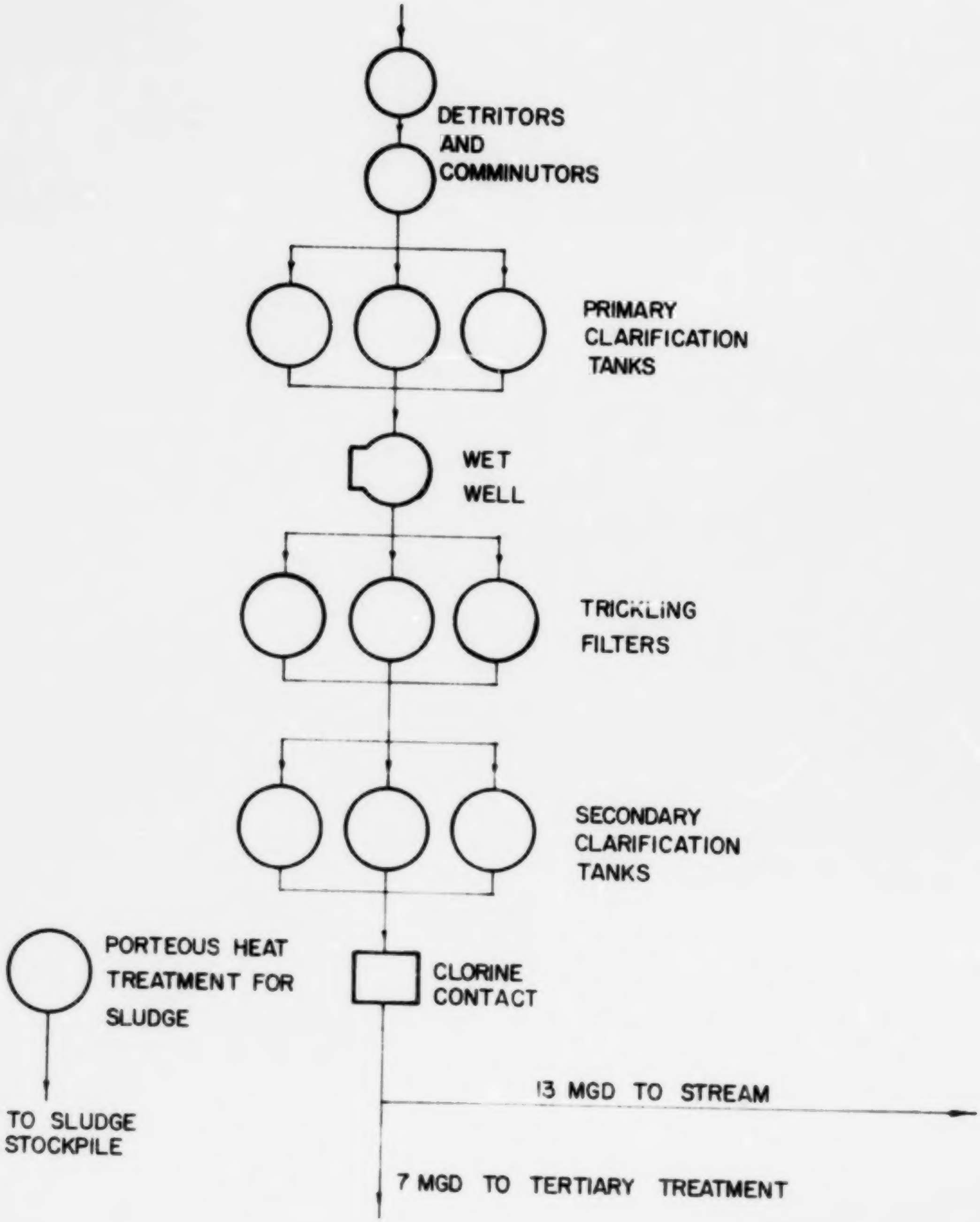
DETRITORS
AND
COMMINUTORS
PRIMARY
CLARIFICATION
TANKS
WET
WELL
TRICKLING
FILTERS
SECONDARY
CLARIFICATION
TANKS
PORTEOUS HEAT
TREATMENT FOR
SLUDGE
CLORINE
CONTACT
13 MGD TO STREAM
TO SLUDGE
STOCKPILE
7 MGD TO TERTIARY TREATMENT

FIGURE A-9
MUNICIPAL SECONDARY WASTE WATER TREATMENT FACILITY
COLORADO SPRINGS, COLORADO

in the two older units is redwood slats, and that in the third is quarry rock. All the filters are covered and equipped with air exchange systems which circulate 18,000 cfm of air that is scrubbed with $KMnO_4$ mist to remove odors. The average recirculation ratio is 1.6:1 with the redwood media units loaded at 200 lbs BOD/1,000 cu ft of media and the rock filter at 45 lbs BOD/1,000 cu ft. Following the trickling filters are three secondary clarifiers each 120 ft in diameter, with an overflow rate of 680 gpd/sq ft. Sludge from these clarifiers is returned to the primary influent. The final secondary process is chlorination with 30 minute detention time. All sludges receive Porteous heat treatment processing. This operation includes: grinding, heating with steam to 360 deg F at 150 to 180 psi, cooling, decanting, thickening and vacuum filtration. Final moisture content is 62 percent.

As seen by the first column of Table A-11 the secondary effluent is of relatively poor quality. As seen in Figure A-10 the tertiary treatment consists of two circuits, termed industrial and irrigation respectively; each involves different processes. The irrigation circuit provides filtration and chlorination with three dual media pressure filters removing suspended solids. The media consists of 3 ft of 1.5 mm sand covered by 5 ft of 2.8 mm anthracite coal. The filters have a surface area of 113 sq ft and an hydraulic design loading of 15 gpm/sq ft for a total design capacity of 7.3 mgd. The filters are backwashed every 8 hours with either air, at 300 cfm/sq ft, water, at 20 gpm/sq ft, or both. After filtration, the water is chlorinated again and discharged to storage reservoirs of 2.5MMG total capacity from which water is pumped upon demand to various irrigational users throughout the city.

The 2 mgd of effluent intended for industrial reuse receives a much higher degree of treatment than the irrigation water. The chlorinated secondary effluent is pumped to a reaction clarifier where a lime dose of 300 to 350 mg/l is added to enhance coagulation and settling. The tank has a diameter of 48 ft, a capacity of 168,000 gal and a 2 hour detention time at a 2 mgd flow rate. The 11.5 pH effluent from the lime reaction clarifier is neutralized to 7.0 in a recarbonation step with CO_2 from the lime recalcination furnace, supplemented by H_2SO_4.

The recarbonation tank is 14 ft in diameter, has a capacity of 16,000 gal, and a detention time of 12 minutes. The water is then filtered through one dual media pressure filter, identical to those previously described fro the irrigation circuit. This filter is intended primarily to protect the carbon adsorption units that follow. If the lime

Table A-11. AVERAGE 1972 WATER CHARACTERISTICS FOR INDUSTRIAL REUSE AT COLORADO SPRINGS, COLORADO

Characteristic mg/l	Stage of Tertiary Treatment			
	Secondary Effluent	Reactor Clarifier Effluent	Lead Carbon Tower Effluent	Polish Tower Effluent
BOD	75-115	47	28.8	22.1
COD	325	145	59.4	43.5
TSS	85	5	2.7	2.7
Turbidity, JTU	56	6	4.5	3.3
Org-N	12-15	--	2.4	1.8
Na	--	--	--	50
Cl	--	--	--	20
Hardness (as $CaCO_3$)	200	240	220	253
Ca^{++}	--	--	100	92
Color	150	35	21.9	11.8
PO_4	30	1.0	1.55	1.53
MBAS	4.6	3.0	1.07	0.43
NH_3-N	--	--	24.5	15.6
NO_3-N	--	--	0.5	0.4
Cu	--	--	--	1-1.5
Cr	--	--	--	0.3
Fe	--	--	--	1-2
pH	7.3	11.2	7.0	7.1
TOC	96	46	25.3	20.4
TDS	--	--	659	661
Total Fecal Coliform	--	--	--	700/100ml

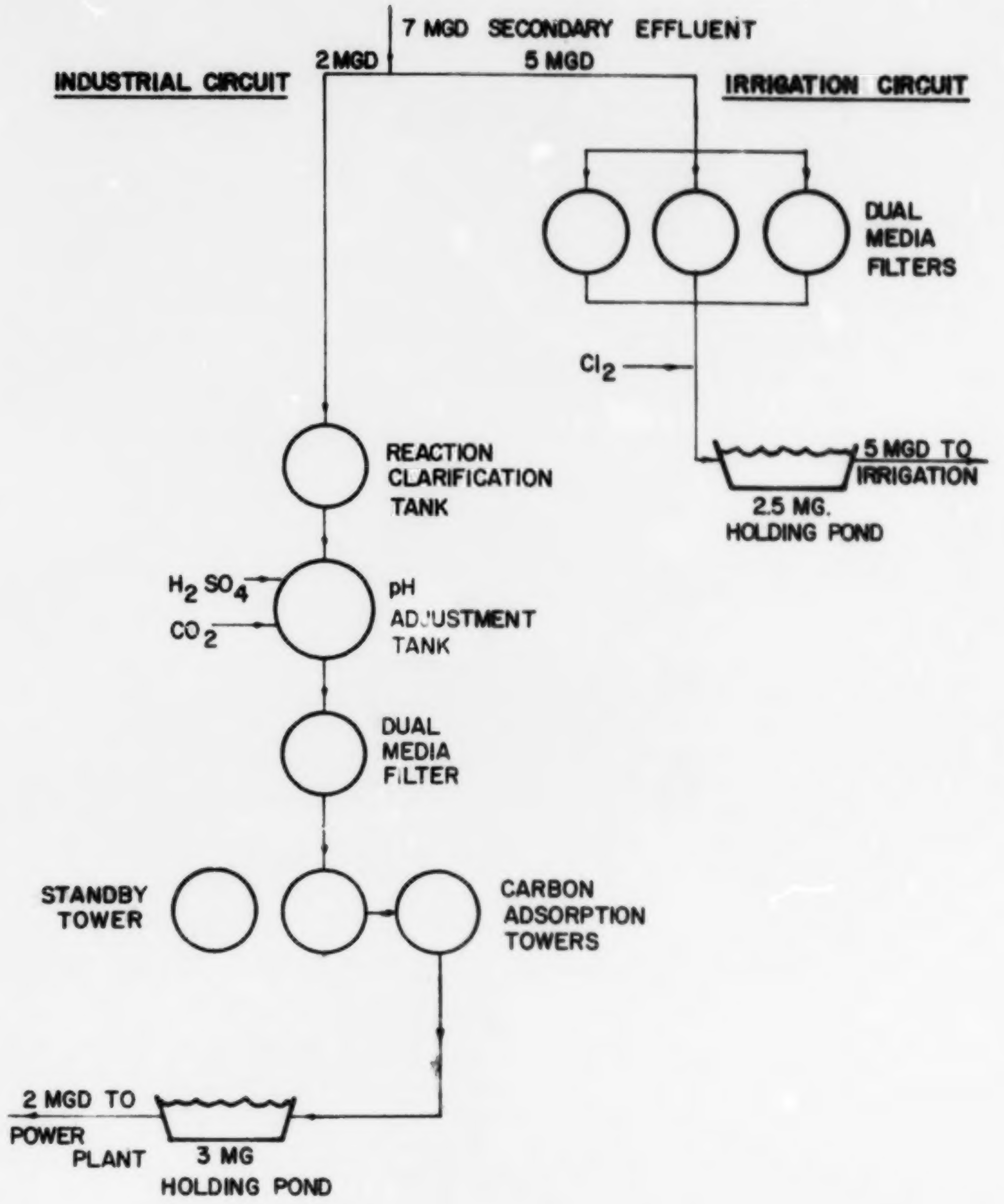
7 MGD SECONDARY EFFLUENT
2 MGD
5 MGD
INDUSTRIAL CIRCUIT
IRRIGATION CIRCUIT
DUAL MEDIA FILTERS
Cl_2
5 MGD TO IRRIGATION
2.5 MG. HOLDING POND
REACTION CLARIFICATION TANK
H_2SO_4
CO_2
pH ADJUSTMENT TANK
DUAL MEDIA FILTER
STANDBY TOWER
CARBON ADSORPTION TOWERS
2 MGD TO POWER PLANT
3 MG HOLDING POND

FIGURE A-10
TERTIARY TREATMENT FACILITY
COLORADO SPRINGS, COLORADO

clarifier should malfunction, losing its sludge blanket, the dual media water filters would remove most of the solids before they could saturate the carbon. Following the filter are two carbon adsorption units operated in series, with a third as standby. Each down flow unit is 20 ft in diameter and has a 10 ft depth of 8 x 30 mesh granular activated carbon totaling 94,000 lbs of carbon per tower. At a design flow of 2 mgd, the loading rate is 4.25 gpm/sq ft (or 0.50 lbs COD removed/lb of carbon) providing a total residence time in the carbon beds of 34 minutes. The carbon towers and sand filter are backwashed daily with either air, at 1,000 cfm/sq ft, water at 10 gpm/sq ft, or both, for 30 minutes. After carbon adsorption, the water is chlorinated to a residual of 0.5 mg/l and stored in a 3 MG butalyne-lined reservoir. Water from this reservoir is presently used for either backwashing filters or irrigation reuse; however, beginning in June 1973, 2 mgd will be used for makeup to the cooling towers of the municipal power plant 2 miles away.

Auxiliary equipment for the industrial circuit includes lime recalcination and carbon regeneration systems. In the lime recalcining operation, the lime mud is drawn from the solids contact clarifier underflow at 7 to 8 percent dry weight and pumped to a spent lime holding tank. An 18 inch centrifuge dewaters the sludge to a cake of about 50 percent solids. This cake is conveyed to a 6 ft diameter, six hearth furnace fired at 1,650 deg F. The calcium carbonates and bicarbonates and the calcium phosphates are converted to calcium oxide and blown to a fresh lime holding tank. The calcium oxide is then slaked in a lime slaker and hydrated to calcium hydroxide which is recycled back to the solids contact clarifer for reuse.

In the carbon regeneration system the spent carbon is conveyed, by water eduction to a holding tank. The carbon is then removed through a rotary proportioning valve to a dewatering screw and the dewatered carbon fed to a 3 ft diameter, six hearth furnace, fired at about 1,650 deg F. After regeneration, the carbon is quenched and moved by water eductors back to the carbon tower. The furnace has a throughput capacity of 75 lbs/hour and the regeneration loss of carbon is about 6.5 percent.

Major problems reported with the treatment process are overloading of the trickling filters (to be alleviated by the new activated sludge plant), and very high maintenance costs for the lime recalcination furnace.

REUSE PRACTICES

In 1960, the city of Colorado Springs initiated the present reclaimed water system for irrigation. After the previously described secondary and dual media filtration treatment, the water is chlorinated and stored in a series of reservoirs. From here the water is piped through approximately 12 miles of pipeline to irrigate city parks, a 27 hole golf course, the Colorado College grounds, industrial landscapes, and a cemetery.

All water outlets from these lines are marked with signs reading "Non-Potable Water"; however, if the water is used accidentally for drinking, the 0.5 mg/l chlorine residual, maintained at all times, should prevent illness.

Industrial reuse will commence in the summer of 1973 when 2 mgd of the industrial circuit tertiary effluent will be supplied to the 250 Mw municipal power plant for cooling tower makeup water. The power plant, located approximately 2 miles distant, is currently using a small volume of the reclaimed water in its stack gas scrubber to remove particulate matter. The renovated water for cooling will satisfy 95 percent of the cooling makeup demand. The remaining 5 percent will come from the public supply.

Due to the high quality of the tertiary effluent, further waste treatment at the industrial site is expected to be minimal. A zinc chromate biological inhibiter, or equivalent, will be added prior to the cooling towers to reduce microorganism growth. Problems with calcium phosphate and calcium sulfate scaling in condenser tubing are possible but not anticipated. The use of stainless steel tubing at the power plant minimizes potential corrosion from the 27 mg/l of NH_3 in the effluent. Close monitoring and system analyses to determine additional treatment, if any, will begin once the reuse program is initiated. The quantities of chemicals and costs cannot be determined until reuse begins.

ECONOMICS

SCS Engineers has estimated that the cost of primary and secondary treatment is approximately \$60/MG, including capital amortization. The tertiary equipment at the facility adds an additional \$260/MG. Thus, a total of \$320/MG is estimated to produce the effluent for reuse. It must be recognized, however, that the industrial tertiary circuit is significantly more expensive than the irrigation tertiary circuit; thus, the \$320/MG is not necessarily applicable for both uses.

The irrigation supply is sold for 7¢/100 cu ft ($94/MG) and produced a revenue of $37,955 in 1971. The resale price of this water to be used for cooling at the power plant has not yet been established. Reuse in this case is oriented toward conservation of the fresh water supply.

The chemical costs at the tertiary plant are indicated in Table A-12.

Table A-12. TYPICAL TERTIARY PLANT CHEMICAL COSTS AT COLORADO SPRINGS*

Material	Cost ($)
Lime	28,163
Acid	26,888
Carbon	12,054
Natural Gas for regeneration	14,207

*1972 total for 588 MG treated

FORT CARSON, COLORADO

INTRODUCTION

The Army base at Fort Carson, Colorado, has been participating in a wastewater treatment and reuse program since 1971. Secondary effluent is given tertiary treatment in preparation for spray irrigation of the base's 18 hole golf course. The tertiary treatment includes mixed media pressure filtration by Neptune Micro-Floc filters.

MUNICIPAL TREATMENT PROCESSES

As a military installation, Fort Carson's population varies considerably. However, an average of 20,000 military personnel and 2,000 civilians (on base 8 hours per day) produce a raw wastewater flow of approximately 1.7 mgd. Roughly 5 percent of this volume is industrial waste, composed primarily of laundry discharges and grease and oil from equipment washing operations. These wastes have no significant deleterious effects on plant operations.

Treatment of an average of 1.7 mgd is illustrated schematically in Figure A-11 and begins with bar screening and comminution followed by gravity settling in two primary clarification tanks. Sludge from these tanks is given conventional 2-stage anaerobic digestion. Secondary treatment is provided by four high rate trickling filters having rock media, 8 ft depths, 73 ft diameters, and loadings of 25 lbs BOD/1,000 cu ft/day. Three final clarifiers have 9.5 ft side wall depths, 55 ft diameters, and an overflow rate of 870 gpd/sq ft based on a 2 hour detention period. (Only two clarifiers are normally utilized).

Sludge from final clarifiers is returned to the primary clarifiers. New controls for effluent recirculation are being constructed to allow a more constant flow through the trickling filters. Secondary effluent is then chlorinated at a dosage of approximately 5 mg/l before discharge into a 0.7 MG pond. Water to be reused for irrigation (0.3 mgd) is pumped from this pond through a pair of Neptune Micro-Floc mixed media filters, while the remainder of the effluent is

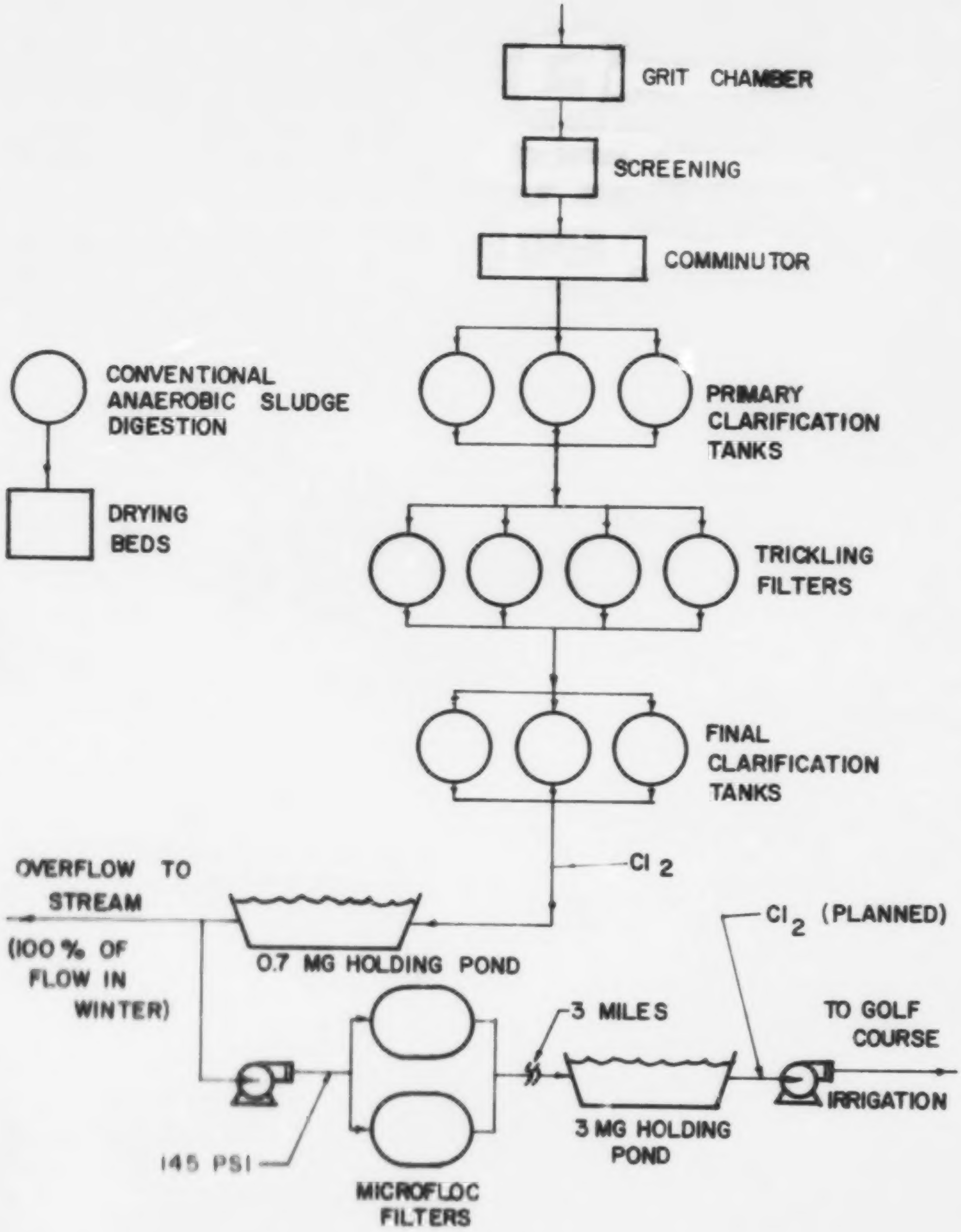
GRIT CHAMBER
SCREENING
COMMINUTOR
CONVENTIONAL ANAEROBIC SLUDGE DIGESTION
PRIMARY CLARIFICATION TANKS
DRYING BEDS
TRICKLING FILTERS
FINAL CLARIFICATION TANKS
OVERFLOW TO STREAM
Cl 2
(100 % OF FLOW IN WINTER)
0.7 MG HOLDING POND
Cl 2 (PLANNED)
3 MILES
TO GOLF COURSE
IRRIGATION
3 MG HOLDING POND
145 PSI
MICROFLOC FILTERS

FIGURE A-11
WASTE WATER TREATMENT FACILITY
FORT CARSON, COLORADO

released to a stream. The 8 ft diameter filters are pressure type, downflow units with a total capacity of approximately 1,000 gpm based on 10 gpm/sq ft filtration rate. The filter beds are comprised of the following media layers from top to bottom:

Media	Depth
Anthracite Coal	13.5 in.
Silica Sand	9.0 in.
Garnet Sand	7.5 in.
Gravel	14.0 in.

Filter backwashing occurs once every 8 hours on the average and takes 1/2 hour to complete. Water filtered through one unit is used, along with water stored in the pipe to the reservoir, to backwash the other. Backwash rates are 15 gpm/sq ft or 1,500 gpm total. A surface backwash at 41 gpm is employed prior to backwashing to remove solids from the filter surface.

Typical effluent quality characteristics of the final reclaimed water are as follows: BOD - 12 mg/l, SS - 17 mg/l, coliforms 0 - 100,000/ml, pH - 7.5.

REUSE PRACTICES

After filtration, the water is pumped 3 miles to a 3 MG storage reservoir from which water is drawn for irrigation of the adjacent golf course and for fire protection of the clubhouse building. Water for irrigation can also be taken from the effluent pipeline before it reaches the reservoir or, if necessary, from the potable distribution system. An average of 0.3 mgd is used on the course during the irrigation season (May to October). Plans have been made to include 40 acres of sewage treatment plant grounds in the renovated water irrigation system. Through the winter months, when no irrigation is done, a total of 10 MG is pumped to the reservoir to compensate for seepage, with the remainder discharged to the stream.

Major problems encountered by the Fort Carson system are associated with the pumping and distribution systems rather than treatment. Numerous breakdowns of pumps and pipeline have hampered efficient operation. Sprinkler heads are presently being modified to alleviate problems caused by algae plugging the spray nozzles. To reduce health hazards, and to meet the requirements of the Army Medical Laboratory, a new chlorination station is planned immediately before application to the golf course to provide a minimum of 2 mg/l Cl_2 residual at the sprinkler head. Referring again to

Figure A-11, it is seen that there is no chlorination at present through the filters or final storage. Regrowth of coliforms in the final 3 MG holding pond cause high coliform counts in the golf course irrigation water.

The greatest maintenance troubles reported at the treatment plant have involved the Micro-Floc filters. Initially designed for total automatic control, malfunctions in this system have forced substantial manual supervision (especially during backwashing) averaging 4 to 6 man-hours per 16 hours of filter operation.

ECONOMICS

Fort Carson realizes substantial savings through the use of reclaimed water for irrigation. Public potable water purchased from the city of Colorado Springs costs $409/MG. Total cost, including capital amortization of all equipment, to produce 1 MG of reclaimed effluent is approximately $363. This cost is deceptive, however, in that only about $105/MG is for tertiary treatment. Approximately $258/MG is required in any case to treat the sewage for disposal to the stream. Comparing $105/MG to $409/MG for fresh water shows a savings of $304/MG to Fort Carson for reuse or approximately $15,000 annually.

COLORADO SPRINGS, COLORADO

(U.S. AIR FORCE ACADEMY)

INTRODUCTION

The U.S. Air Force Academy is utilizing reclaimed wastewater to fill a series of non-potable reservoirs which provide recreational fishing for the cadets and supply irrigation water for academy grounds. This program of water reclamation and reuse was initiated in 1957 upon completion of the academy and sewage treatment plant construction.

TREATMENT PROCESSES

The wastewater treatment plant provides secondary treatment to an average of 1.2 mgd in serving a population of 16,700 including 4,400 cadets. The flow contains an insignificant amount of industrial wastes but has relatively high amounts of grease from food services.

Figure A-12 shows the treatment process. Treatment begins with mechanical bar screening and grinding in comminutors, followed by passage through a grit and grease removal unit. The grease removal efficiency is poor, and grease clogging of trickling filter units has occurred. Three circular primary clarifiers remove settleable solids, transferring the sludge to a conventional anaerobic sludge digestion process. Primary effluent is fed to three rock media, primary trickling filters of 60 ft diameter with organic loadings of 50 lbs BOD/1,000 cu ft/day. Intermediate clarification follows the primary trickling filters. The water then passes into a second set of standard rate trickling filter units identical to the primary filters. Preceding final clarification, the water enters an aeration tank operated as an activated sludge unit. This tank is 10.5 ft in depth and provides 4 hours of retention time at 400 mg/l MLSS concentration. Aeration is accomplished with a brush aerator, and activated sludge is recycled from the final clarifiers. Four final clarification tanks are each 30 ft in diameter with a design weir overflow rate of 7,800 gal/lf/day under conditions of no recirculation to the trickling filters. This overflow

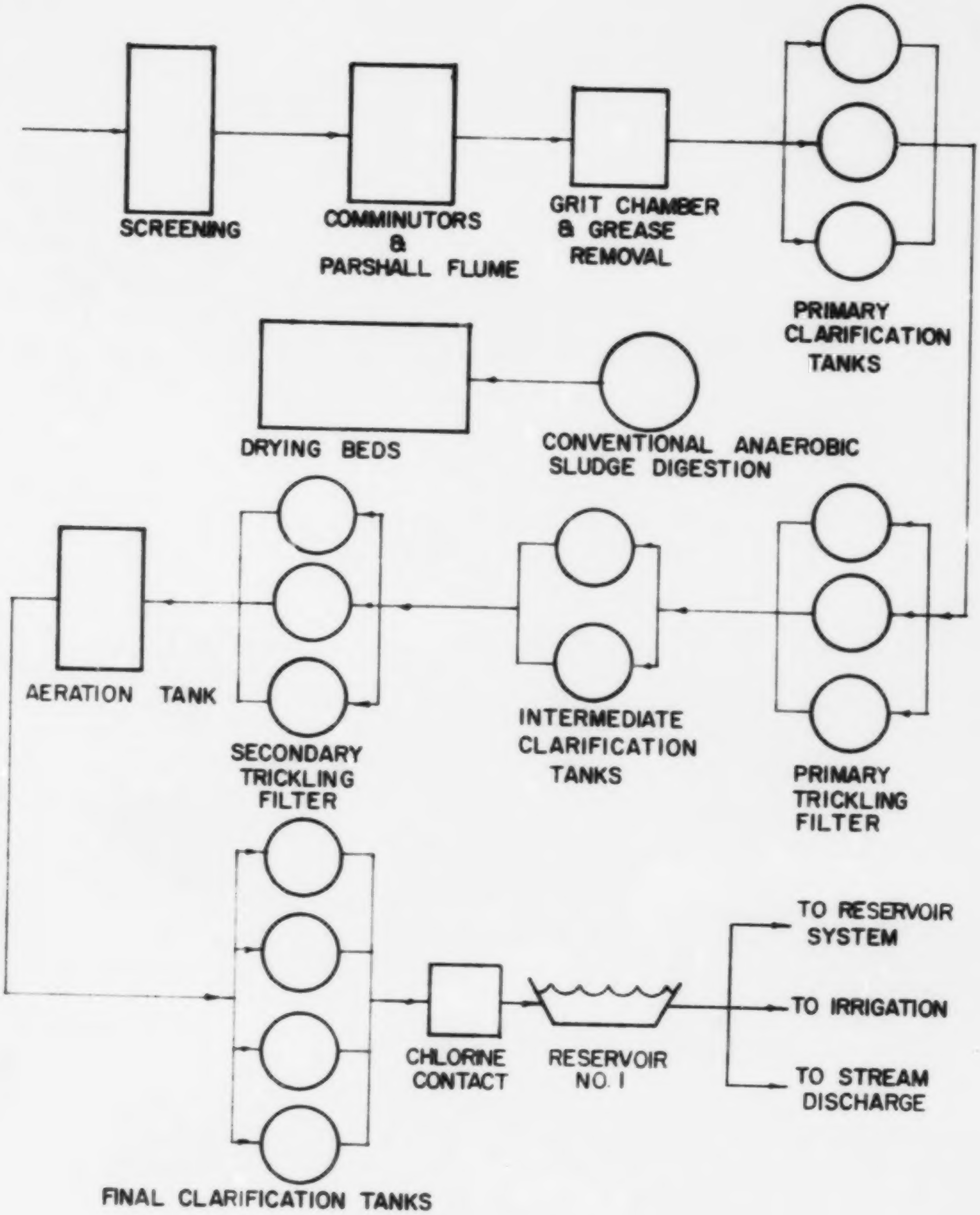
SCREENING
COMMINUTORS & PARSHALL FLUME
GRIT CHAMBER & GREASE REMOVAL
PRIMARY CLARIFICATION TANKS
DRYING BEDS
CONVENTIONAL ANAEROBIC SLUDGE DIGESTION
AERATION TANK
SECONDARY TRICKLING FILTER
INTERMEDIATE CLARIFICATION TANKS
PRIMARY TRICKLING FILTER
TO RESERVOIR SYSTEM
TO IRRIGATION
TO STREAM DISCHARGE
CHLORINE CONTACT
RESERVOIR NO. 1
FINAL CLARIFICATION TANKS

FIGURE A-12
WASTE WATER TREATMENT FACILITY
UNITED STATES AIR FORCE ACADEMY
COLORADO SPRINGS, COLORADO

rate can be increased when recirculating to augment low flow through the filters. The clarifier effluent is then chlorinated for approximately 20 minutes to a 0.5 mg/l chlorine residual before release to a creek or the non-potable reservoir system.

Average effluent quality characteristics are given in Table A-13. It is surprising that the effluent is not of better quality in view of the extensive secondary treatment provided. The superintendent stated that the plant is not an optimum design hydraulically, and the activated sludge unit BOD removals are poor due to inability to maintain a suitable floc.

Table A-13. AVERAGE EFFLUENT CHARACTERISTICS AT THE U.S. AIR FORCE ACADEMY, COLORADO SPRINGS, COLORADO

Characteristic	Concentration mg/l
BOD	20
SS	30
PO_4	12
NO_3	35-40
NH_3	5
pH	7.1

Additional treatment is provided for water used for recreational fishing and irrigation. It consists of long-term residence (85 day maximum) in four reservoirs.

Presently, only the second reservoir is aerated. Three surface aerators driven by a 30 HP compressor comprise the Helixer System that diffuses approximately 135 lbs of oxygen into the lake in a 24 hr period. The primary purpose of this aeration is to induce circulation and turnover of the lake waters to increase natural surface transfer of oxygen from the atmosphere. Aeration systems are also planned for reservoirs No. 1 and No. 3 when funds become available.

REUSE PRACTICES

Reuse at the Air Force Academy is seasonal. From May to October all the effluent (approximately 1.2 mgd) is discharged to the non-potable reservoir system. During late fall and winter months, when there is no irrigation or fishing, the effluent is discharged to a stream. To improve the quality of water discharged to the stream, all effluent is first sent through non-potable reservoir No. 1.

The reservoir system consists of three soil-cement lined ponds and one clay-lined pond connected in series with a total storage capacity of 149 MG. In addition to the 1.2 mgd effluent discharge, a system of eight non-potable wells can supply a total of 2.9 mgd to the four reservoirs.

Water from all four reservoirs is used for irrigation. During the irrigation season, approximately 3 feet of reclaimed water is applied to 347 acres of academy lands including cadet athletic fields, a cemetery, parade grounds, highway median strips, a golf course, and the stadium. Some odor problems have been encountered with the use of water from the first lake, especially if this water remains in the irrigation distribution system too long. Plugging of irrigation nozzles with algae and debris is also an occasional problem. It is anticipated that construction of a 1/4 inch screen to filter the final effluent will help relieve this problem. Algal blooms are experienced in all the reservoirs in the late summer. High nutrient loads in the reservoir system stimulate algal growth. It is the opinion of the academy technical staff that CO_2 is the limiting nutrient rather than PO_4^{-3}, and that reduction of benthos organisms (that release CO_2) by inducing lake turnover through aeration will reduce the CO_2 concentrations in the water, thereby reducing algal growth. Low concentrations of $CuSO_4$ algacide have also been used in the past to discourage aquatic plant growth. Table A-14 lists water quality characteristics of the reservoirs.

For several years, a program of research stocking has been carried out in non-potable reservoirs No. 2 and No. 3. Recreational fish stocking was limited to reservoir No. 4. This lake is approximately 40 feet deep and holds 20 MG. It is the last lake in the series, is situated in a natural drainage basin, and has the best water quality (see Table A-11). The DO content is over 5 mg/l near the lake surface, but rapidly deteriorates to an oxygen demand at the deeper levels.

A full spectrum of aquatic plant and animal life is evident. The reservoir has been periodically stocked with 6" to 8" trout, small and large mouth bass, bluegill, and channel catfish fingerlings.

The low temperature of Reservoir No. 4 (only occasionally do surface temperatures rise to 70° in late summer months) favors a trout population rather than warm water species; e.g., bass, bluegill, and catfish. However, the rainbow trout are more sensitive to dissolved oxygen concentration, and sporadic kills of the trout have occurred with low DO. Fish spawning activity is also insignificant because the

Table A-14. RESERVOIR WATER CHARACTERISTICS AT U.S. AIR FORCE ACADEMY, COLORADO SPRINGS, COLORADO

Characteristic	Reservoir No.			
	1*	2*	3**	4**
Temp., Deg C	12.2	10.0	10.5	10.0
DO, mg/l	2.8	13.9***	4.5	6.1
PO_4, mg/l	22.0	26.4	3.0	3.0
pH	--	8.2	7.5	7.5
Total alkalinity, mg/l	--	--	98.0	77.0
Turbidity, JTU	--	5.0	--	--
COD, mg/l	60.5	--	--	--
BOD, mg/l	5.0	--	--	--
SS, mg/l	20.0	--	--	--
CO_2, mg/l	--	--	8.6	5.7

*Data obtained in April 1971.

**Data obtained are average surface readings for the period April 17 through May 5, 1961.

***Not typical; supersaturated due to algal activity.

lake does not have the shallow, sandy bottom preferred for spawning, and most of the trout stocked in the spring are caught by fishermen during the summer season.

Although much remains to be learned about these reservoirs, several conclusions are reported by the Academy. Year-round potential for trout is limited based on the demonstrated inability of reservoir No. 4 to support trout over the long term. Fish kill experiences here date back over a decade, and this reservoir has the best water quality of the series. Trout potential, if such exists on a predictable basis, lies in growing a crop over the colder months in the highly fertile ponds No. 2 and No. 3. The aeration of reservoir No. 2 could create conditons capable of supporting a trout population. This project is under investigation. Undoubtedly year-round potential of the latter ponds lies in the management of more tolerant warm water fishes, such as has been empirically determined for Pond No. 4. Periodic (3-4 year) stocking of fingerling bluegills eventually results in some king-size specimens (just under one pound). Channel catfish likewise do reasonably well. Although such fishing opportunity cannot be considered Utopian, it is nonetheless judicious use of the water resource and provides diversity to the overall program.

ECONOMICS

The reclaimed water irrigation program consumes approximately 1,000 acre-ft or 336 MG a year. Public water purchased from the city of Colorado Springs costs $409/MG. Therefore, the Academy is realizing a savings in water purchase costs of roughly $137,000 per year.

In addition to the 347 acres irrigated with reclaimed water, 485 acres are watered with potable city supplies. Unfortunately, the costs of expanding the existing non-potable reclaimed water irrigation system to include this land are prohibitively high.

There are no tangible economics benefits from the recreational fishing program as no fees are charged to cadets or employees of the academy to use the lakes. The costs of the trout and bass stocking programs are minimal.

BALTIMORE, MARYLAND

INTRODUCTION

The city of Baltimore, through its Back River Wastewater Treatment Plant, supplies an average of 120 mgd to the Sparrows Point Plant of Bethlehem Steel Corporation. In terms of volume, this is the largest reuse operation in the nation, and possibly in the world. In operation since 1942, the reclamation program has long been a success, both technically and economically. It is remarkable that in the intervening 30 years similar arrangements have not been instituted between other municipalities and large basic metal manufacturing plants in America.

MUNICIPAL TREATMENT PROCESSES

Figure A-13 illustrates schematically the major treatment processes at the municipal plant and management of the reclaimed water during transportation to the steel plant.

After screening, grit removal and primary clarification, the 180 mgd average flow of primary effluent is split into parallel secondary treatment process lines.

Approximately 160 mgd is treated with standard rate trickling filters with a total surface area of 30 acres and a depth of 8.5 ft. Final clarification following the trickling filters is provided in 5 tanks designed for 1.5 hours detention and 900 gpd/sq ft overflow rate. Sludge is returned to the grit chamber for eventual removal in the primary clarifier.

In the other secondary treatment process line, approximately 20 mgd of primary effluent is treated in two activated sludge tanks measuring 60 ft x 376 ft x 15 ft deep. Return activated sludge is normally 20 percent and air supply is around 1 cu ft/gal. The activated sludge final clarifiers are 126 ft diameter x 16 ft deep. Waste activated sludge is returned to the grit chamber.

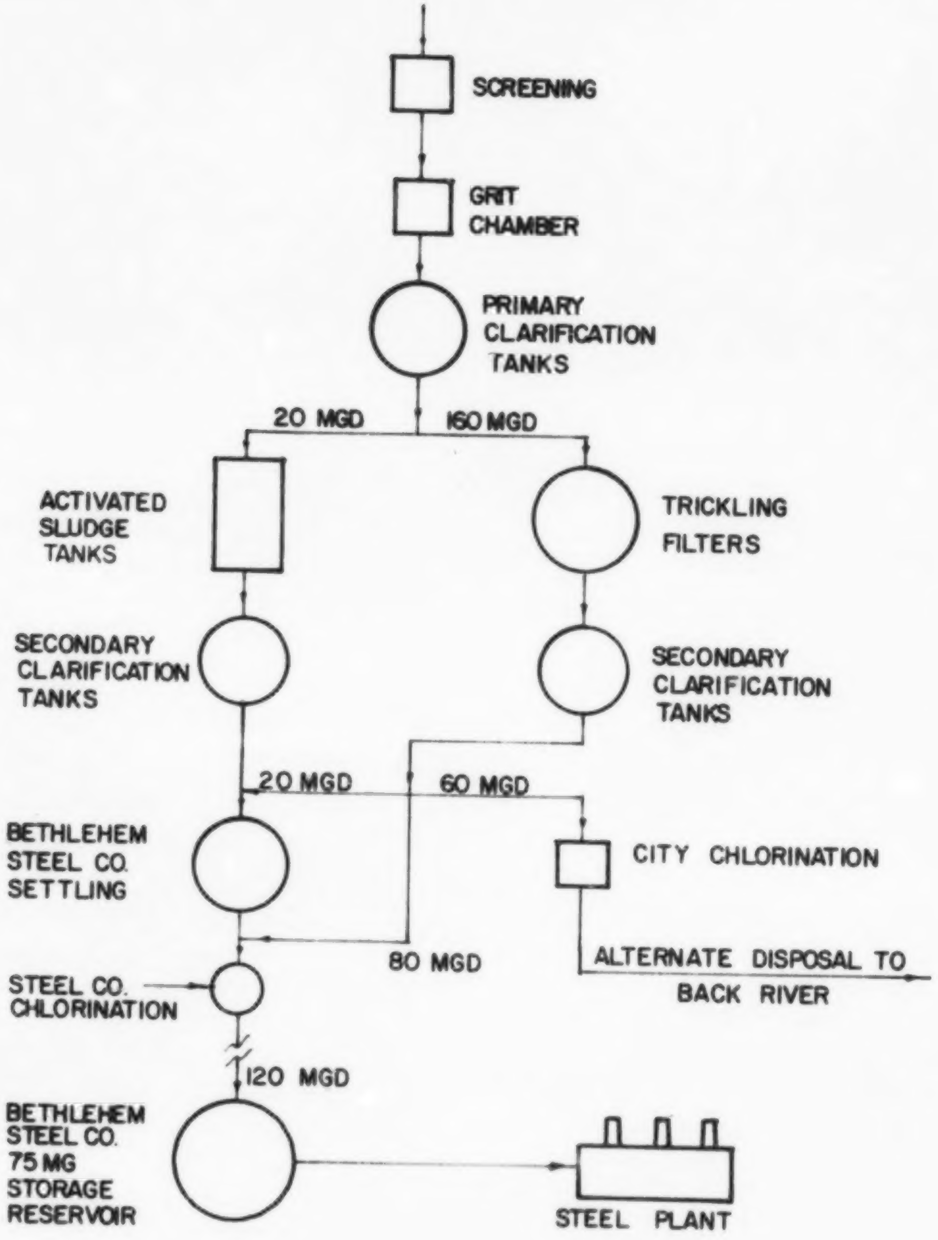
SCREENING
GRIT CHAMBER
PRIMARY CLARIFICATION TANKS
20 MGD
160 MGD
ACTIVATED SLUDGE TANKS
TRICKLING FILTERS
SECONDARY CLARIFICATION TANKS
SECONDARY CLARIFICATION TANKS
20 MGD
60 MGD
BETHLEHEM STEEL CO. SETTLING
CITY CHLORINATION
80 MGD
ALTERNATE DISPOSAL TO BACK RIVER
STEEL CO. CHLORINATION
120 MGD
BETHLEHEM STEEL CO. 75 MG STORAGE RESERVOIR
STEEL PLANT

FIGURE A-13
MUNICIPAL WASTE WATER TREATMENT FACILITY
BACK RIVER PLANT
BALTIMORE, MARYLAND

Referring again to Figure A-13 it is seen that the city discharges to waste approximately 60 mgd which is chlorinated at a dosage of approximately 10 mg/l. The remaining 120 mgd is directed to the Bethlehem Steel Corp. post-treatment facilities. Average effluent quality to Bethlehem Steel is shown in Table A-15 below.

Table A-15. AVERAGE EFFLUENT CHARACTERISTICS (UNCHLORINATED) BACK RIVER PLANT, BALTIMORE, MARYLAND

Characteristic	Concentration (mg/l)	Characteristic	Concentration (mg/l)
BOD	46	MPN	5×10^6
SS	44	Zn	1.0
TDS	450	Fe	0.5
Na	75	PO_4	12.0
pH	7.0	NO_3	4.0

The effluent quality shown in Table A-15 is suitable for cooling water by Bethlehem Steel because its cooling use is "once through", i.e., there is no recirculaion of cooling water for multiple use. Other cooling water applications described in this report, e.g., Burbank, California and Odessa, Texas, supply recirculating cooling systems and require higher quality effluent to operate successfully.

Specific quality parameters have been agreed upon between the city of Baltimore and Bethlehem Steel. The following monthly average limits are stipulated:

- pH 6.5 to 7.8
- SS 25 mg/l (Activated Sludge)
  50 mg/l (Trickling Filter)
- Cl 175 mg/l

Since the city must also meet the more stringent requirements of the state of Maryland, these contract limits are generally not exceeded.

USER TREATMENT PROCESSES

Bethlehem Steel operates a tertiary sedimentation facility adjacent to the city's Back River Plant. This facility consists of two 15 mgd capacity and one 20 mgd capacity package units, however, due to hydraulic problems their combined capacity is only 40 mgd.

The 40 mgd is blended with the 80 mgd not further settled, and chlorinated before being pumped 5 miles to a 75 MG capacity equilization reservoir at the steel plant. The Sparrows Point Plant of Bethlehem Steel removes effluent from the reservoir as needed for cooling and manufacturing processes.

The equilization reservoir has a current deposition of sludge varying from 0 to 14 inches which is never removed. Floating sludge is returned to the municipal treatment plant via sewers.

Quality assurance is maintained by sampling for chlorine, chloride ion, and turbidity levels at 4-hour intervals at the continuously-manned tertiary plant. Currently it is reported that the treated wastewater must be by-passed approximately 12 hours per month due to unacceptable turbidity or when the chloride concentration exceeds 175 mg/l. Although this occurs infrequently, runoff from salted roads during winter months and excessively high tides can cause difficulty in maintaining the 175 mg/l limit.

REUSE PRACTICES

The municipal effluent is utilized in many aspects of steel plant operation. Specific uses occur in furnace cooling, gas cleaning, quenching, spray cooling, mill roll cooling, closed heat exchangers, bearing cooling, process temperature control, descaling systems, hydraulic systems, fire protection, air conditioning, and road equipment washing. Figure A-14 depicts a typical flow schematic of water use in the steel industry.

Reuse can be discontinued for only short times because of the steel plant's dependence upon the municipal supply. After a 12 hour period, brackish water from the Back River and other sources is utilized. After 24 hours a portion of the steel operation would be forced to shut down, although this has never occured.

Bethlehem Steel is required by contract to accept a minimum of 100 mgd from the city treatment plant. In addition to the municipal wastewater supply, the industry has a 550 mgd capacity brackish water system as well as other sources of both potable and non-potable supply.

Plans for future improvements and increased reuse are currently being considered at Bethlehem Steel. The Blast furnaces, now using brackish cooling water, will be partially converted to reuse effluent, and a new blast furnace will be designed to reuse effluent exclusively. The company is also

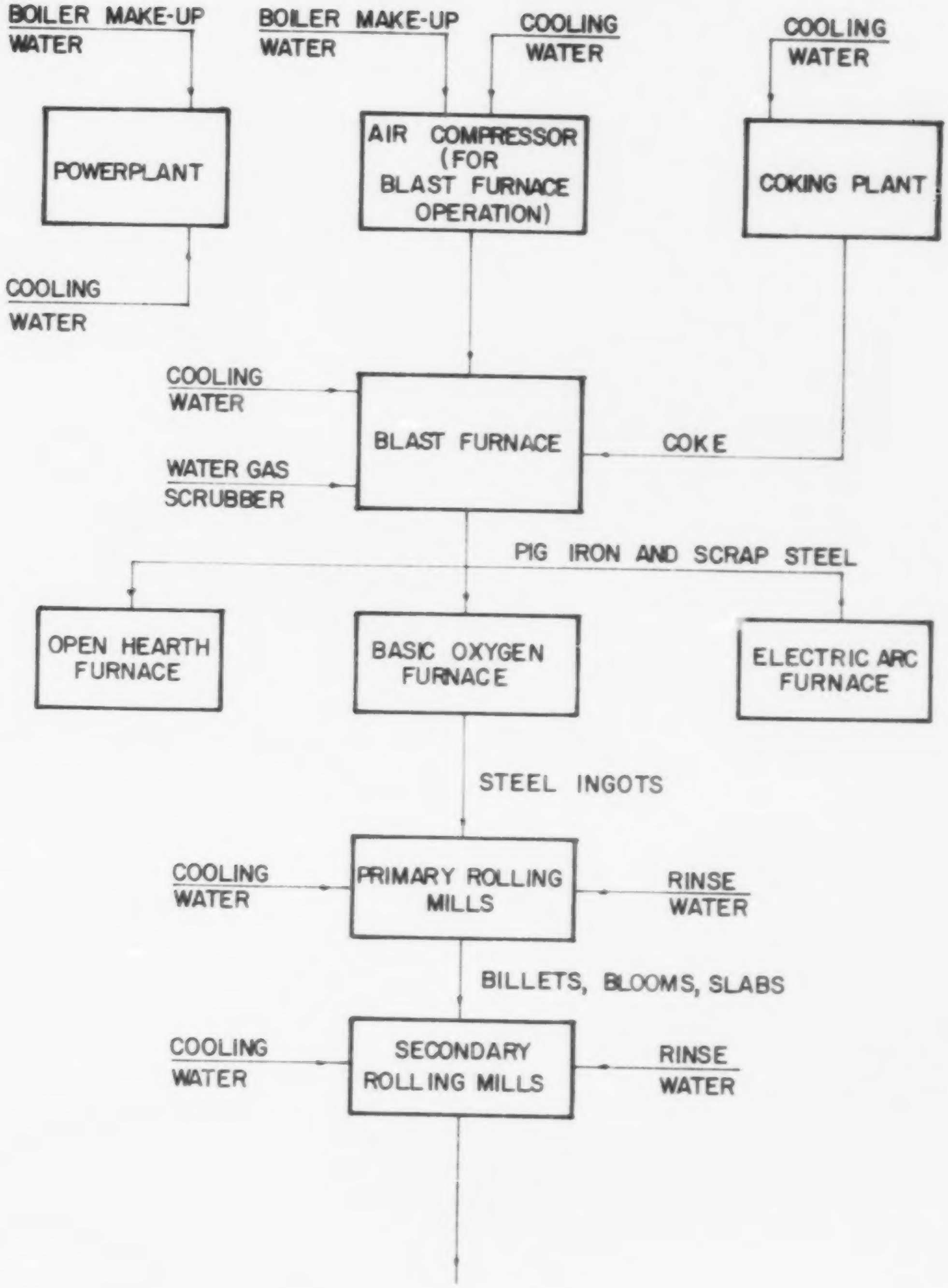
BOILER MAKE-UP WATER
BOILER MAKE-UP WATER
COOLING WATER
COOLING WATER
POWERPLANT
AIR COMPRESSOR (FOR BLAST FURNACE OPERATION)
COKING PLANT
COOLING WATER
COOLING WATER
BLAST FURNACE
COKE
WATER GAS SCRUBBER
PIG IRON AND SCRAP STEEL
OPEN HEARTH FURNACE
BASIC OXYGEN FURNACE
ELECTRIC ARC FURNACE
STEEL INGOTS
COOLING WATER
PRIMARY ROLLING MILLS
RINSE WATER
BILLETS, BLOOMS, SLABS
COOLING WATER
SECONDARY ROLLING MILLS
RINSE WATER

FIGURE A-14
WATER USE AT A GENERALIZED INTEGRATED STEEL MILL

planning for greater in-plant recycling of the effluent prior to discharge. The entire plant wastewater is treated prior to discharge, with separate treatment provided for sanitary and industrial wastes.

ECONOMICS

Because of the scale of operations involved, the unit cost of treatment for reuse is very low at Baltimore. The Steel Company is charged $500/month for each average daily flow increment of 12.5 mgd, an equivalent of $1.33/MG. In 1972, total reclaimed water sale was $60,000.

Total 1971-72 operating and maintenance costs for the Back River Plant was $2.4 million, divided approximately as follows:

. Labor	$1.70 million
. Contractural services	.25 million
. Material and supplies	.33 million
. Equipment replacement	.15 million

Operating and maintenance cost per mg equals only $37. It was not possible to obtain costs from Bethlehem Steel Corp. for their treatment and transportation. An engineering estimate by SCS is that $11/MG is a conservative figure.

LAS VEGAS, NEVADA

INTRODUCTION

The city of Las Vegas and Clark County Sanitation District each operate a secondary sewage treatment plant to serve the Las Vegas, Nevada area. A portion of each plant's effluent is reclaimed for use as cooling tower makeup water and in irrigating local farms and golf courses.

The effluent is very high in TDS and of average quality in other respects. The Nevada Power Company provides tertiary treatment to the effluent prior to reuse in cooling towers at two of its power plants.

MUNICIPAL TREATMENT PROCESSES

The city of Las Vegas municipal treatment plant is schematically shown in Figure A-15. An average of 27 mgd of influent raw sewage is screened and grit removed before primary sedimentation. Secondary treatment consists of three 180 ft diameter trickling filters with 4 ft of rock media and three rectangular secondary sedimentation tanks each measuring 184 ft by 34 ft by 8 ft deep. The secondary clarifiers provide for a recirculation ratio of 2:1 with an overflow rate of 800 gpd/sq ft.

After 40 minutes chlorine contact, the renovated water flows to a holding pond at the Nevada Power Company Sunrise Station cooling towers, and to the Las Vegas Wash. Three farms utilizing renovated water take their supply straight from the chlorine contact tank. On an annual average, 23 mgd is wasted to the wash, 3 mgd is used by the farms, and 1 mgd by the Power Company. Table A-16 tabulates the total reuse activities in the Las Vegas Valley.

The Clark County facility, as shown in Figure A-16, is very similar to that of the city of Las Vegas. An average raw sewage influent volume of 12.5 mgd, after screening, is introduced to four primary clarifiers measuring 18 ft by 220 ft by 8.5 ft deep, which have a detention time of 2 hours and an overflow rate of 950 gpd/sq ft. These are followed

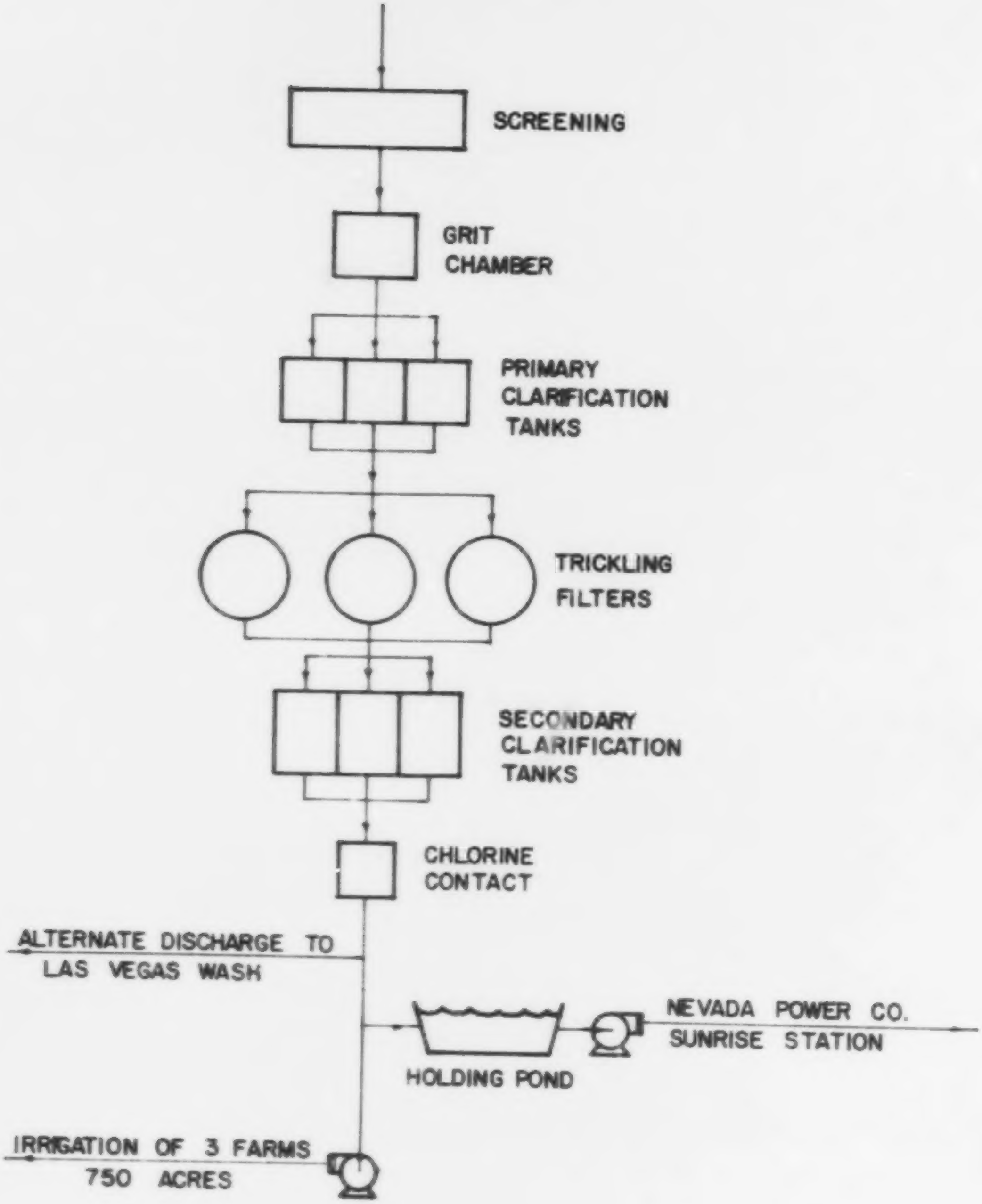
SCREENING
GRIT CHAMBER
PRIMARY CLARIFICATION TANKS
TRICKLING FILTERS
SECONDARY CLARIFICATION TANKS
CHLORINE CONTACT
ALTERNATE DISCHARGE TO LAS VEGAS WASH
HOLDING POND
NEVADA POWER CO. SUNRISE STATION
IRRIGATION OF 3 FARMS 750 ACRES

FIGURE A-15
MUNICIPAL WASTE WATER TREATMENT FACILITY
LAS VEGAS, NEVADA

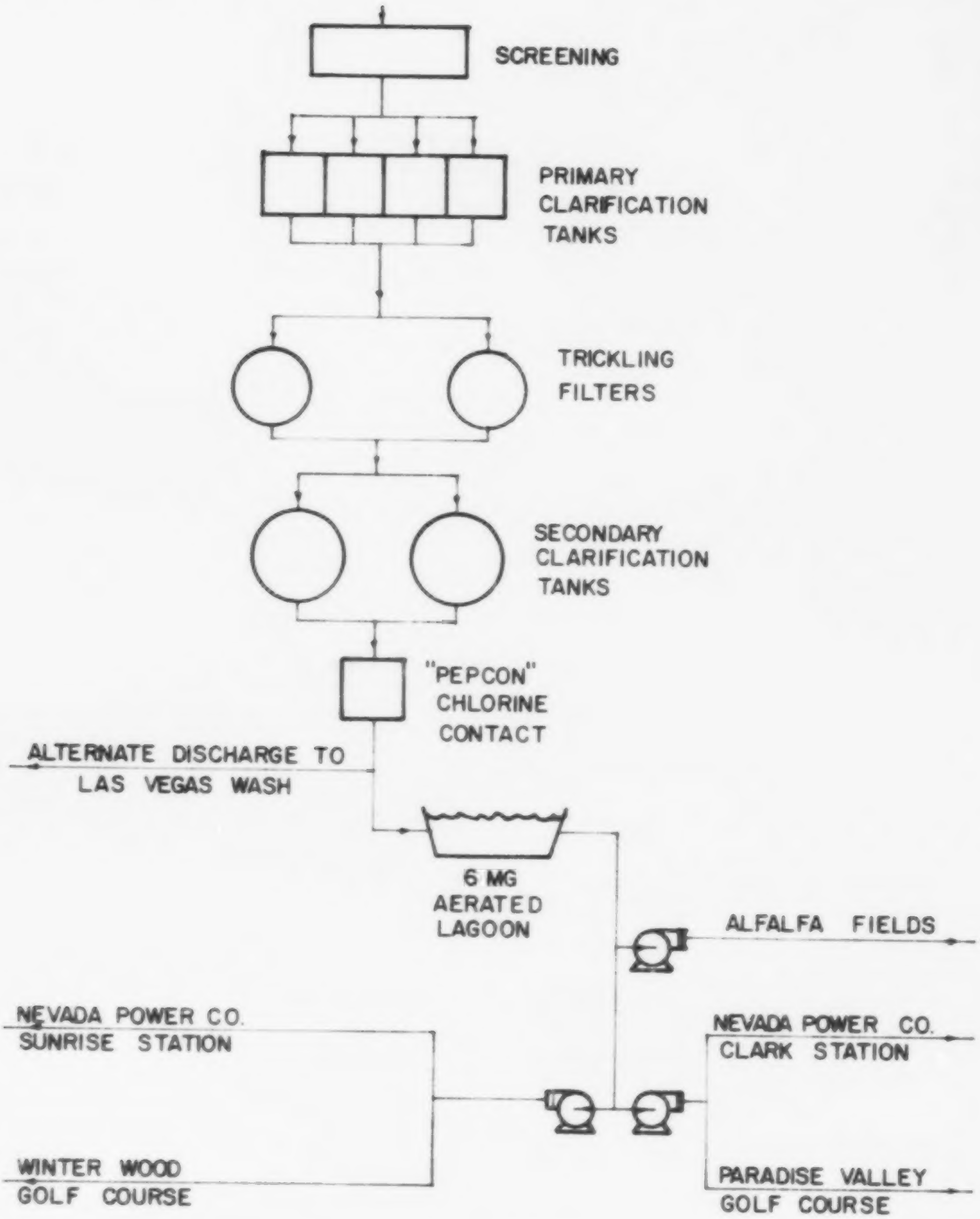
SCREENING
PRIMARY CLARIFICATION TANKS
TRICKLING FILTERS
SECONDARY CLARIFICATION TANKS
"PEPCON" CHLORINE CONTACT
ALTERNATE DISCHARGE TO LAS VEGAS WASH
6 MG AERATED LAGOON
ALFALFA FIELDS
NEVADA POWER CO. SUNRISE STATION
NEVADA POWER CO. CLARK STATION
WINTER WOOD GOLF COURSE
PARADISE VALLEY GOLF COURSE

FIGURE A-16
CLARK COUNTY WASTE WATER TREATMENT FACILITY
LAS VEGAS, NEVADA

by two high-rate trickling filters each 175 ft diameter with 5 ft of rock media. A recirculation ratio of 1.5:1 is maintained providing a BOD loading of 60 lb/100 cu ft. Two secondary clarifiers provide detention time for the trickling filter effluent of 2 hours. The overflow rate is 760 gpd/sq ft.

The final treatment step consists of chlorine contact for 20 minutes prior to discharge to a 6 MG asphalt paved holding pond for reclaimed water storage. The effluent is pumped to the Sunrise and Clark Power Stations of the Nevada Power Company, two golf courses, and alfalfa fields. Maximum distance to any user is 1.5 miles. As seen in Table A-16, on an average basis, 8.3 mgd is discharged to Las Vegas Wash, 3 mgd for irrigation, and 1 mgd to power plant cooling tower makeup.

Both plants average 85 to 90 percent reduction in BOD and suspended solids. Table A-16 tabulates average effluent characteristics for each plant. The significant difference between the effluents is in the high TDS of the county plant effluent due to the higher TDS in the water supply of the county area.

Table A-16. AVERAGE EFFLUENT CHARACTERISTICS IN LAS VEGAS VALLEY

Characteristic	Concentration (mg/l)	
	Las Vegas City Plant	Clark County Plant
BOD	21	19
SS	18	22
Cl	295	330
TDS	985	1,550
pH	7.6	7.6

REUSE PRACTICES

The municipal effluents from both the city of Las Vegas and Clark County Sanitation District are utilized for 35 percent of the supply in the cooling towers of the Nevada Power Company power generation stations. Tertiary treatment at the power stations consists of chlorination followed by cold lime treatment and lagooning. Problems reported by the power company are occasional algae buildup in the county aerated lagoon and septicity of the renovated water supply upon arrival at the power company due to anaerobic conditions in the force main. Installation of floating aerators in the lagoon following the county treatment facility has helped reduce this problem by maintaining higher dissolved oxygen levels in the final effluent.

The irrigation reuse operations on two golf courses have experienced several problems including significant odors, and salt accumulations in the soil due to the high TDS of the effluent. Table A-17 summarizes municipal wastewater reuse practices in the Las Vegas area.

Table A-17. SUMMARY OF REUSE VOLUMES IN LAS VEGAS VALLEY

Description	Volume, mgd	
	Las Vegas City Plant	Clark County Plant
Avg. total effluent volume	27.0	12.5
Avg. volume to reuse	3.8	4.3
High volume to reuse	6.5	5.0
Low volume to reuse	1.0	1.3
Avg. Volume to power plant	1.0	1.3
Avg. volume to farms*	2.8	1.0
Avg. volume to golf courses**	-	2.0
Avg. discharge to surface waters	23.2	8.2

*Ranges from high of 8 mgd in summer to low of 1 mgd in winter.

**Estimated volume, summer use is approximately double winter use.

ECONOMICS

Table A-18 lists pertinent data relative to the reuse of effluent by Nevada Power Company. The cost of effluent to Nevada Power Company averages $15/MG plus amortized costs for capital investment in the pumping and transportation facilities. The latter costs raise the delivered price of effluent to $20/MG and $30/MG respectively at the power stations.

The delivered effluent requires additional clarification and nutrient removal before it can be used for cooling tower makeup water. Including amortization of treatment facilities, it is estimated that the tertiary treatment by the power plants averages approximately $200/MG.

Table A-18. SUMMARY OF EFFLUENT REUSE BY NEVADA POWER COMPANY IN LAS VEGAS NEVADA

Description	Power Plant	
	Clark Station	Sunrise Station
Present capability, KW	130,000	85,000
Use of effluent	Cooling tower	Cooling tower
Source of effluent	Clark County San. District	City of Las Vegas
Alternate source of water	None	Clark County San. District
Avg. effluent used, mgd	1.3	1.0
Effluent cost, $/MG*	30	20
Capital cost of treatment facilities at power station, $**	400,000	400,000
Chemical cost, $/day***	75	50
Labor cost, $/day	48	48
Other costs, $/day	5	5
Total cost, $/MG****	223	195

*Includes amortization of storage and transport facilities for effluent between sewage treatment plant and power generation station. Actual charge for effluent less capital amortization is approximately $15/MG for each power plant.

**Estimated by SCS Engineers.

***Sunrise is disproportionately lower because effluent used is of better quality. See Table A-16.

****Includes amortization of treatment facility cost at 5.5 percent interest, 25-year life divided by 365 days x average effluent volume used.

AMARILLO, TEXAS

INTRODUCTION

The city of Amarillo, Texas treats municipal wastewater and provides reclaimed effluent to Southwestern Public Service Company and Texaco Oil Company for use as cooling water makeup. They also supply water to agricultural concerns for irrigation of approximately 2,300 acres of crop land. The River Road Wastewater Treatment Plant supplies all reclaimed water for industrial use and will be the only municipal plant discussed in this section. Renovated water for irrigation is supplied by the Hollywood Road Plant in Amarillo.

The use of reclaimed water is a vital part of plant operation at both Texaco and Southwestern Public Service Company. Aside from economic savings to both municipality and industry, it is likely that discontinuation of reclaimed water use would severely disrupt operation of the Southwestern power plant. When the irrigation of 2,500 acres of crop land is added to the balance, reclamation is obviously a vital resource to the community.

MUNICIPAL TREATMENT PROCESSES

The activated sludge plant at River Road handles an average flow of 10 mgd. Of this influent flow, 7 percent is contributed by industrial discharges which include meat packing, laundries, and food processing plant wastes. Although these wastes comprise 29 percent of the total BOD load to the plant, they appear to have no significant adverse effects on either plant operation or efficiency.

Primary treatment consists of screening, grit removal, and gravity clarification, followed by storage in a 3.7 MG equalization lagoon to stabilize flow to the aeration tanks. Secondary treatment involves conventional spiral flow activated sludge with a 4 hour detention time, mixed liquor concentration to 2,600 mg/l, 40 percent sludge recirculation rate, and 1.8 cu ft of air added per gal. Circular secondary clarifiers with overflow rates of 600 gpd/sq ft precede final chlorination and discharge to an 18 MG holding pond.

Solids handling consists of sludge thickening and conventional anaerobic digestion. Figure A-17 shows a schematic diagram of the treatment process.

Typical effluent quality characteristics of the River Road plant are shown in Table A-19 along with comparative listings of city well and lake supplies. The reclaimed water quality is within the limits specified in the contract with industry, also shown in Table A-19.

Problems with activated sludge upsets due to filamentous organisms and high grease content of the raw waste have been reduced considerably by close regulation of industrial waste discharges. Persistant problems with sludge bulking during winter months have forced usage of concentrated hydrogen peroxide in final clarifiers as a specific biocide. Consideration is also being given to alum addition to increase coagulation and enhance settling.

USER TREATMENT PROCESSES

Southwestern Public Service Company, an electric utility, has been treating reclaimed city sewage effluent since 1961 at its Nichols Station Plant in Amarillo. Reclaimed water usage varies from 1.5 to 5 mgd and satisfies the entire cooling water demand for the 485 Mw capacity power plant. Southwestern's treatment facility has a maximum capacity of 13.7 mgd and consists of cold lime treatment, pH adjustment, storage and chlorination prior to use in the cooling towers. Figure A-18 shows a schematic flow diagram of the treatment process. Two of four cold lime treaters are currently in use and are operated at chemical feed rates of 2.5 to 3.0 lbs lime and 0.25 lbs alum per 1,000 gals treated. Phosphate reductions to less than 2.0 mg/l and substantial silica removal is achieved in this unit, preventing problems of orthophosphate and silicate scaling. The treated effluent from the cold lime softener has a high pH of 10.0 to 10.5, an hydroxide alkalinity of 50 to 100 mg/l, and is very unstable. In this state the water will scale calcium carbonate very rapidly; therefore, acid is added to lower the pH to 9.2 and prevent after-precipitation and scaling. Storage is in two lagoons with a volume of 3 MG.

Problems with biofouling and scaling of heat exchange equipment and piping are minimized by heavy chlorination and pH control to 7.0. The chlorine treatment, however, was somewhat corrosive to the system as condenser tubing was pitted and the pH difficult to control during chlorination. Some slime was found in condenser tubing even with the high chlorine dosage. Amertap systems have recently been installed in one of the three units at Nichols Station to circulate

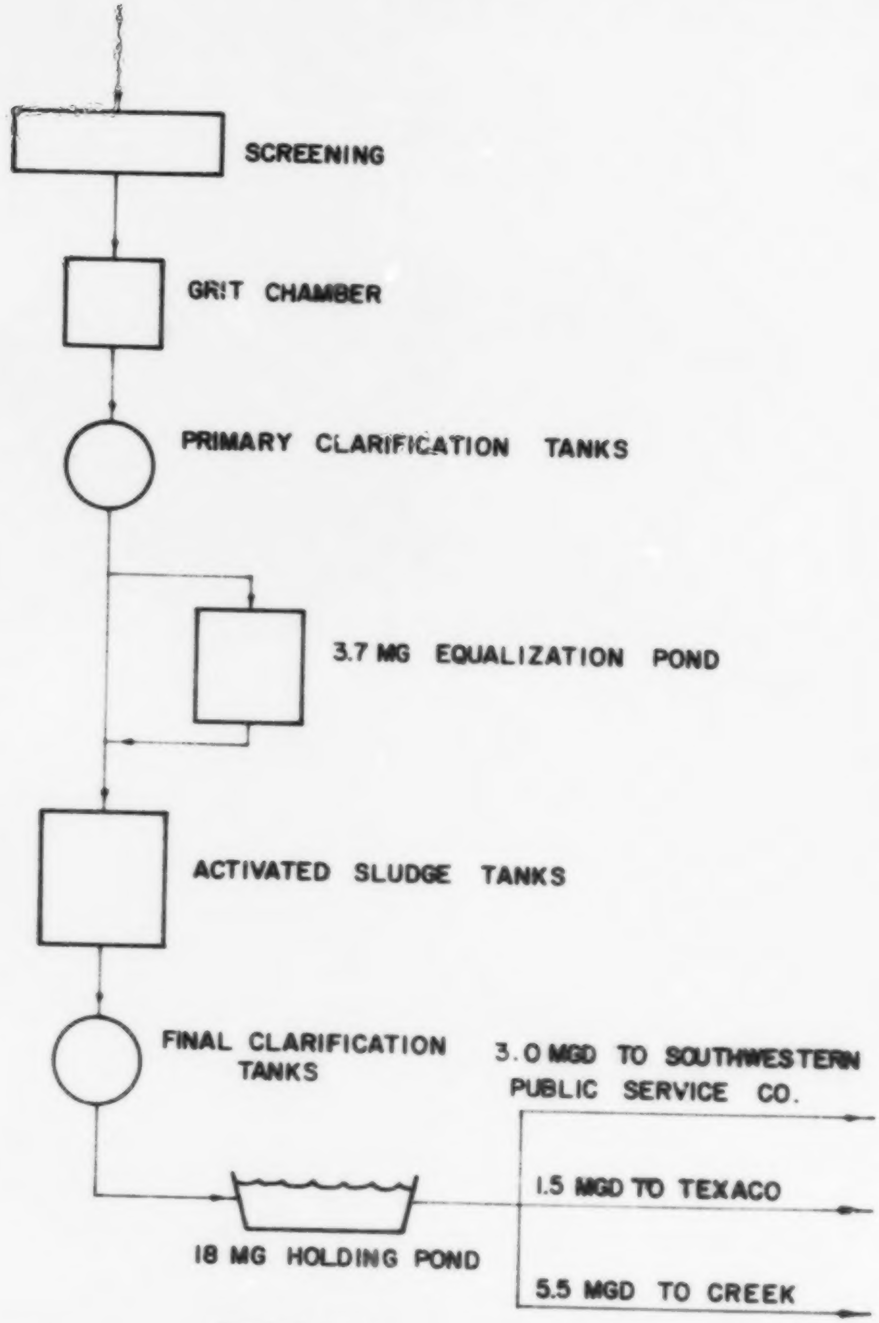
SCREENING
GRIT CHAMBER
PRIMARY CLARIFICATION TANKS
3.7 MG EQUALIZATION POND
ACTIVATED SLUDGE TANKS
FINAL CLARIFICATION TANKS
3.0 MGD TO SOUTHWESTERN PUBLIC SERVICE CO.
1.5 MGD TO TEXACO
18 MG HOLDING POND
5.5 MGD TO CREEK

FIGURE A-17
MUNICIPAL WASTE WATER TREATMENT FACILITY
RIVER ROAD PLANT
AMARILLO, TEXAS

Table A-19. COMPARATIVE AVERAGE WATER CHARACTERISTICS IN AMARILLO, TEXAS

Characteristic mg/l	Source			
	Well Water	Lake Water	Treated Municipal Effluent	Contract Limits
Ca	40	58	61	
Mg	26	23	24	
Na	34	210	300	
Fe	0	0		
M-Alkalinity	230	162	287	
Hardness	210	240	253	
SiO_2	56	3	10	
NH_3-N	0	0.43	24	
NO_3-N	1	0.6	4	
PO_4	0	0.02	20	
Cl	11	225	300	
SO_4	28	225	280	
TDS	360	950	1,400	1,400
SS	0	0	15	25
BOD	0	0	15	25
COD	0	0		
Chlorine Residual	0.2	0.6	0.6	0.1
pH	7.7	7.8	7.7	6.8-9.0

*All analytical data except pH is expressed as the ion.

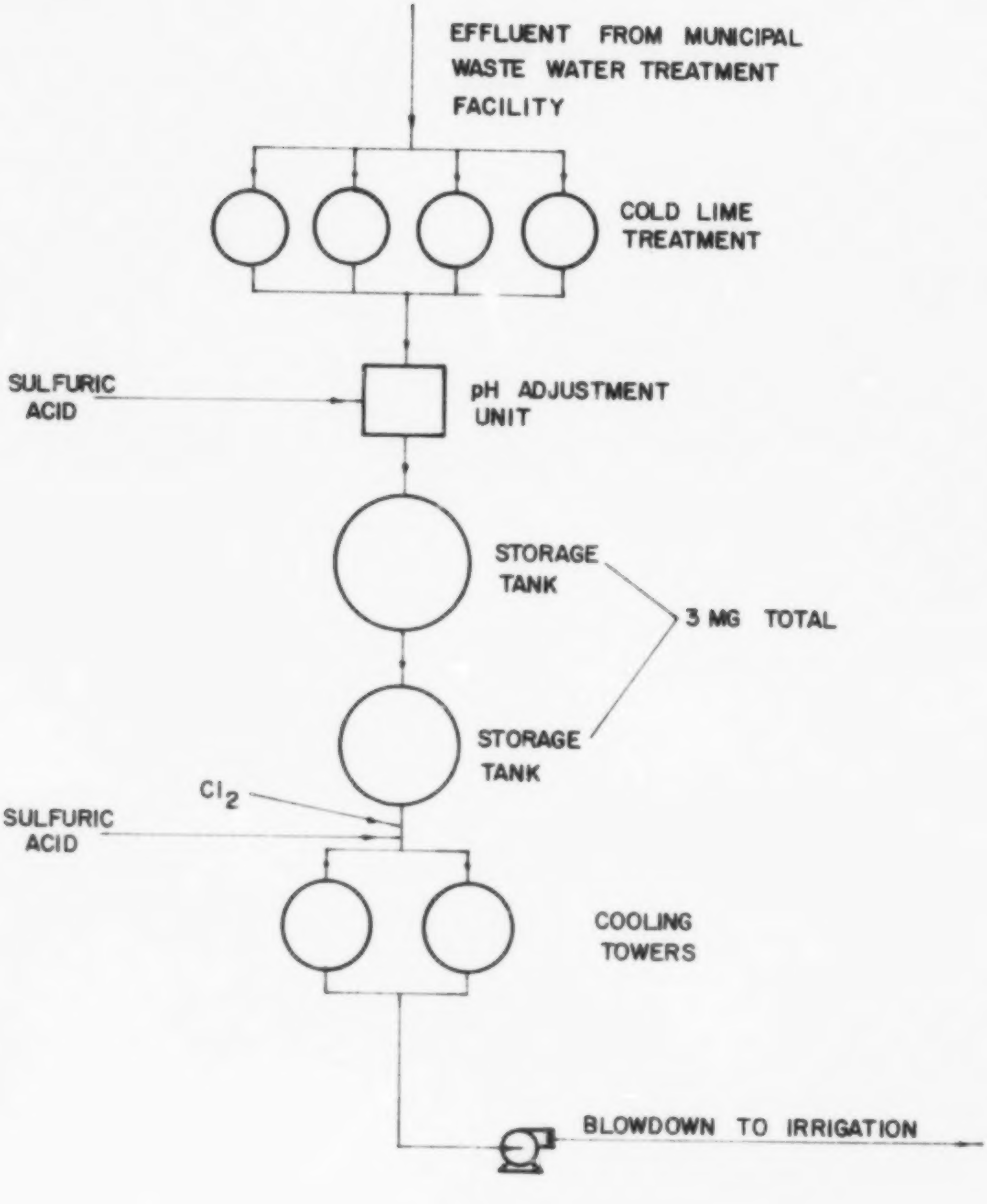
EFFLUENT FROM MUNICIPAL WASTE WATER TREATMENT FACILITY
COLD LIME TREATMENT
SULFURIC ACID
pH ADJUSTMENT UNIT
STORAGE TANK
3 MG TOTAL
STORAGE TANK
Cl_2
SULFURIC ACID
COOLING TOWERS
BLOWDOWN TO IRRIGATION

FIGURE A-18
RECLAIMED WATER TREATMENT FACILITY
SOUTHWESTERN PUBLIC SERVICE CO.
AMARILLO, TEXAS

Table A-20. AVERAGE WATER CHARACTERISTICS FOR REUSE AT SOUTHWESTERN PUBLIC SERVICE COMPANY, AMARILLO, TEXAS

Constituent (mg/l)	Amarillo Fresh Water	Treated Municipal Effluent	Cooling Tower Makeup	Cooling Water in Tower
Ca	68	74	72	376
Mg	29	36	10	51
Na	111	134	134	689
K	3	8	8	39
NH_3	0	12	12	1
HCO_3	104	134	24	20
CO_3	0	0	36	0
SO_4	254	281	336	1,728
Cl	60	78	78	388
NO_3	0	3	2	90
PO_4	0	48	2	10
SiO_2	5	17	6	30
pH	8.1	7.3	9.2	7.0
BOD	0	15	2	6

*Analysis results corrected for calculated cation and anion balance.

All analytical data except pH expressed as the ion.

sponge rubber balls through the condenser tubes, thus maintaining a cleanness factor of 85 to 90 percent. It is hoped that this action will eliminate the need for chlorination. Blowdown water from the cooling towers is used by a local farmer to irrigate alfalfa, wheat, maize, and other high salt tolerant grasses.

Typical effluent qualities produced by the Southwestern Public Service Company treatment system are listed in Table A-20, along with the qualities of fresh water, sewage effluent, and water within the cooling towers.

Reclaimed water treatment at Texaco consists of cold lime treatment for phosphate, silica, and SS removal with some softening also effected. Water is fed directly to the cooling towers from the cold-lime treatment with chlorination of cooling tower recirculating water for control of biofouling. Storage facilities totaling 6.5 MG are used only for emergency as the regular inflow bypasses the storage sites.

Texaco's treatment facility is diagrammed in Figure A-19. Typical reclaimed water quality values obtained through treatment are shown in Table A-21.

Table A-21. AVERAGE TREATED EFFLUENT CHARACTERISTICS FOR REUSE AT TEXACO REFINERY, AMARILLO, TEXAS

Characteristic	Concentration (mg/l)
TDS	1,100
PO_4	5
SiO_2	34
SO_4	220
Cl	207
Hardness	130
Total Hardness	225
M-Alkalinity	270

All analytical data expressed as the ion.

REUSE PRACTICES

Of the 10 mgd treated at the River Road Plant, an average of 3 mgd is purchased by Southwestern Public Service Company and 1.5 mgd by the Texas Oil Refinery; all this water is used for cooling water makeup. The remaining 5.5 mgd is discharged to a creek and must meet Texas State discharge standards of 20 mg/l SS and 20 mg/l BOD. It is expected

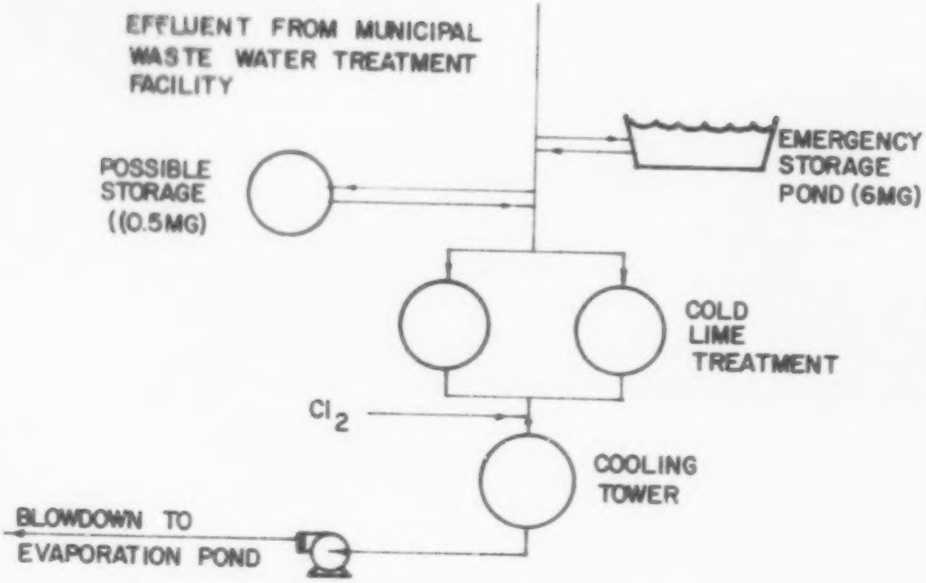
EFFLUENT FROM MUNICIPAL WASTE WATER TREATMENT FACILITY
EMERGENCY STORAGE POND (6MG)
POSSIBLE STORAGE ((0.5MG)
COLD LIME TREATMENT
Cl_2
COOLING TOWER
BLOWDOWN TO EVAPORATION POND

FIGURE A-19
RECLAIMED WATER TREATMENT FACILITY
TEXACO OIL REFINERY
AMARILLO, TEXAS

that by 1975, virtually all effluent from the River Road Plant will be reused by industry, since Southwestern Public Service plans increased reclaimed water usage due to plant expansion.

The Texaco Refinery in Amarillo also uses effluent from the River Road municipal treatment plant for cooling purposes. The 20,000 barrel/day refinery treats and reuses an average of 1.5 mgd of reclaimed water, which satisfies all its cooling water demands. Renovated water has not been used recently for low pressure boiler feed; however, it was utilized in previous years to supply up to 100 percent of the boiler feed water when well water supplies were insufficient.

The main problem encountered at the Texaco refinery due to reclaimed water use are: (1) increased usage of algacides and biocides to control growth of bacteria and algae due to the presence of nutrients in the effluent; and (2) sludging tendencies that produce soft deposits on heat exchange equipment. Another problem when renovated water was used in the boilers was corrosion of copper parts by ammonia produced from decomposition of organic matter. High TDS concentrations (1,300 mg/l), foaming, and scaling problems discouraged further use of treated reclaimed effluent in the boilers.

ECONOMICS

In the case of Southwestern Public Service Company, the economic decision to use reclaimed water is based on long-term availability, long term cost, and effect on total capital investment, rather than immediate lowest cost.

One of the major reasons for consideration of sewage effluent water is its availability. As the need for power increases, the flow of wastewater increases. The natural balance thus provides the cooling water requirements for the necessary additional generation needs.

The long term cost of sewage effluent for industrial water for cooling approaches the same cost as more valuable fresh water. The use of treated sewage effluent conserves high quality fresh water.

Public fresh water presently costs approximately 19¢/1,000 gal; however, this cost would increase significantly if Texaco and Southwestern abandoned the use of reclaimed water in favor of the city supply, because the city would be forced to locate and drill extensive new wells in order to meet the added 7.8 mgd peak industrial demand.

Cost data for the two reusing industries in Amarillo are listed in Table A-22.

TABLE A-22

REPORTED COSTS OF RECLAIMED WATER REUSE IN AMARILLO, TEXAS

ITEM	COST ($/MG)	
	SPSC	TEX
Reclaimed water cost (1)	80	90
Operation:		
- Labor	20	8
- Utilities	(inc. in labor)	12
- Supplies	59	25
Maintenance	13	12
Capital Amort.	68 (2)	137 (3)
Total	240	284

(1) Difference between two industrial costs due to graduated price scale.

(2) Estimated by SCS Engineers

(3) Based upon Texaco figures as follows:

In-plant treatment facilities, $132, 400, at 6% for 20 years, = $40/MG/yr., and for contribution to city treatment plant and reclaimed water transportation facilities, $964,000, at 3½% for 30 years, = $97/MG/yr.

BIG SPRING, TEXAS

INTRODUCTION

The Cosden Oil and Chemical Company of Big Spring, Texas has used reclaimed water from the Big Spring sewage treatment plant since 1943. Presently Cosden utilizes 0.5 mgd of treated effluent for low pressure boiler feed makeup water. The boiler steam is used for a great variety of consumptive purposes within this large petro-chemical complex.

MUNICIPAL TREATMENT PROCESSES

Figure A-20 shows a flow diagram of the 0.5 mgd Big Spring treatment plant which supplies the reclaimed water. The raw sewage contains no industrial wastes. Built in 1943, the plant uses the outmoded Hays aeration process of two stage aeration without activated sludge recirculation.

The Hays aeration facility includes: screening, primary and intermediate settling, first and second stage aeration, final clarification, anaerobic digestion and storage in a 1 MG capacity holding pond. Typical quality characteristics reported for the treated wastewaters are: BOD-35 mg/l, SS-10 mg/l, TDS-960 mg/l, pH-7.0, and hardness-250 mg/l.

Adjacent to the Hays plant shown in Figure A-20, the city operates a trickling filter plant with an average flow of 2.3 mgd. This plant receives raw sewage from a different area of Big Spring. Infiltration of the sewers causes this sewage to contain up to 1,000 mg/l chlorides which renders the effluent unsuitable for reuse by the Cosden plant.

Improvements in the present sewer system are underway to greatly reduce the amount of groundwater infiltration into the sewer lines. If successful, this program should improve the quality of the effluent from the city's trickling filter plant and make its reuse by Cosden a possibility; however, according to Cosden engineers, future usage of this water for cooling is doubtful due to the corrosive properties of residual organics in the sewage effluent and the high costs of algicides and corrosion inhibitors that would be needed.

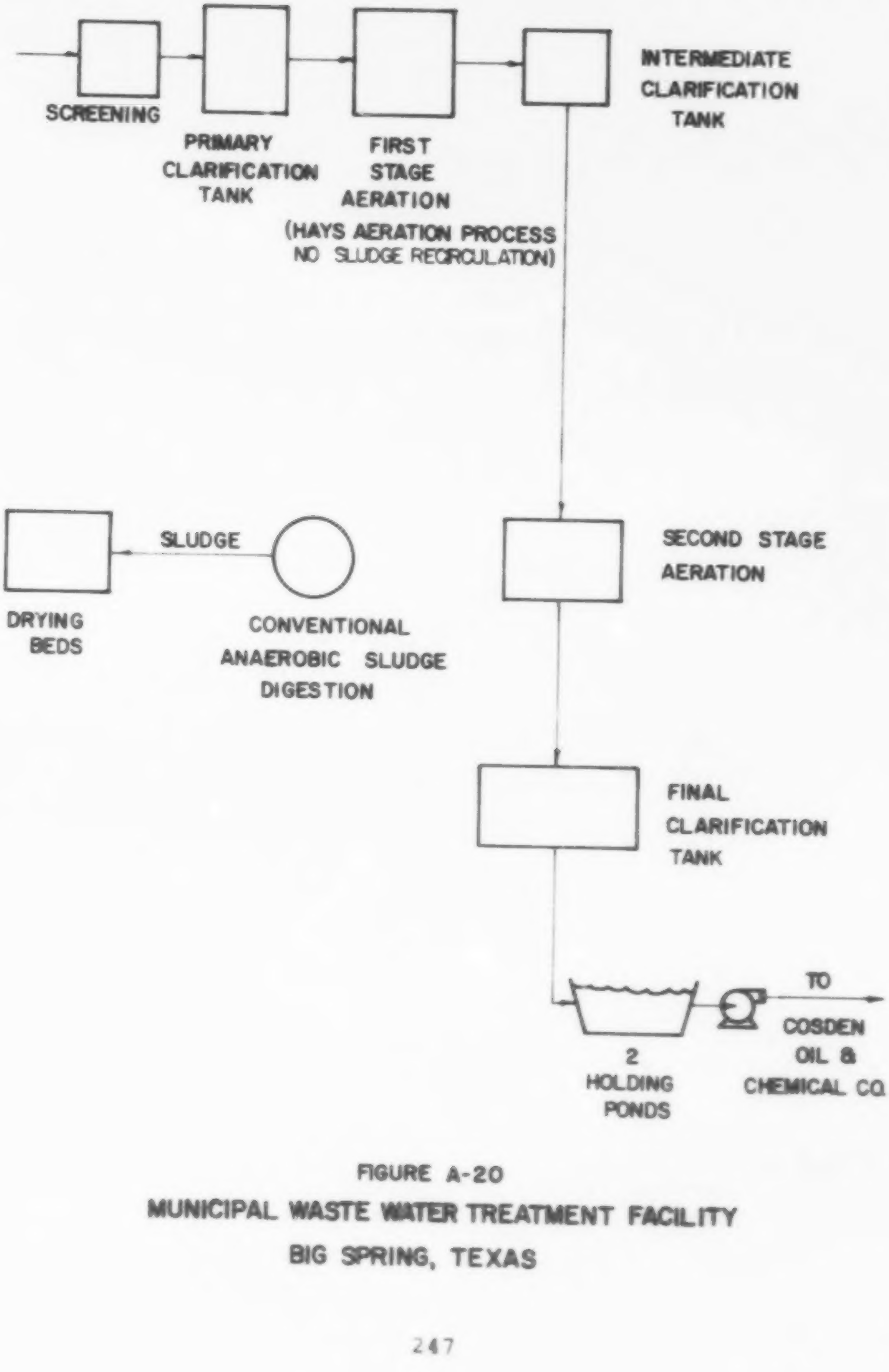
SCREENING
PRIMARY CLARIFICATION TANK
FIRST STAGE AERATION
(HAYS AERATION PROCESS NO SLUDGE RECIRCULATION)
INTERMEDIATE CLARIFICATION TANK
SECOND STAGE AERATION
SLUDGE
DRYING BEDS
CONVENTIONAL ANAEROBIC SLUDGE DIGESTION
FINAL CLARIFICATION TANK
2 HOLDING PONDS
TO
COSDEN OIL & CHEMICAL CO.

FIGURE A-20

MUNICIPAL WASTE WATER TREATMENT FACILITY

BIG SPRING, TEXAS

USER TREATMENT PROCESSES

Treatment by the Cosden Oil and Chemical Co., preceding use in its 175 psig boilers, includes: hot process lime softening, anthracite filtration, hot zeolite softening and deaeration. Figure A-21 shows a schematic flow diagram of the Cosden Oil treatment plant. Table A-23 gives important quality characteristics of the effluent from the sewage treatment plant as well as water qualities after the lime and zeolite softening.

Table A-23. AVERAGE WATER CHARACTERISTICS AT VARIOUS STAGES OF TREATMENT FOR REUSE AT COSDEN OIL, BIG SPRING, TEXAS

Constituent (mg/l)	Stage of treatment		
	Treated municipal effluent	Hot lime softener effluent	Hot zeolite softener effluent
Cations			
Ca	50	20	0-1
Mg	84	8	0-1
Na	494	405	431
Total	636	433	433
Anions			
HCO_3	386	-	-
CO_3	-	164	164
OH	-	22	22
SO_4	70	100	100
Cl	180	147	147
Total	636	433	433
Total hardness	142	28	0-2
Methyl orange alkalinity	386	186	186
pH	7.3	9.95	-

REUSE PRACTICES

The Cosden Oil and Chemical Company processes over 12 million barrels of crude oil annually. The 0.5 mgd of treated effluent supplied by the city of Big Spring equals approxi-

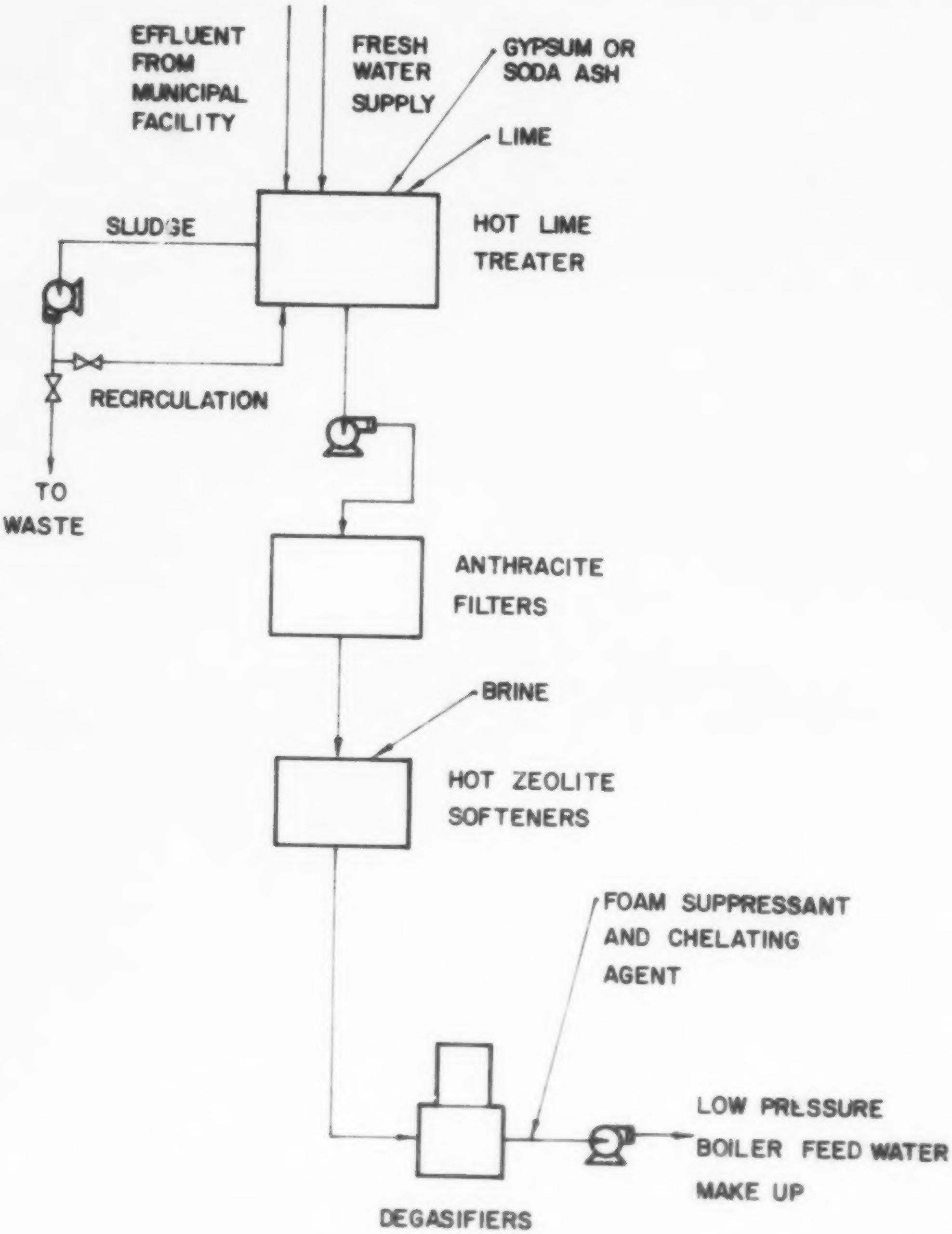
EFFLUENT FROM MUNICIPAL FACILITY
FRESH WATER SUPPLY
GYPSUM OR SODA ASH
LIME
SLUDGE
HOT LIME TREATER
RECIRCULATION
TO WASTE
ANTHRACITE FILTERS
BRINE
HOT ZEOLITE SOFTENERS
FOAM SUPPRESSANT AND CHELATING AGENT
LOW PRESSURE BOILER FEED WATER MAKE UP
DEGASIFIERS

FIGURE A-21
RECLAIMED WATER TREATMENT FACILITY
COSDEN OIL AND CHEMICAL CO.
BIG SPRING, TEXAS

mately 25 percent of Cosden's total water demand. The remainder of the supply comes from Lake Thomas and is used primarily for cooling water. Table A-24 lists the various ways in which steam produced from sewage effluent water has been successfully used over many years of operation at Cosden Oil and Chemical Company.

At present, the reclaimed effluent is used only to feed 175 psig boilers. Condensate from these boilers also supply high quality makeup water for the high pressure boilers (600 psig).

Solutions of amine, caustic, and ammonia for various treating uses have been made up using steam condensate for many years. There has been no problem noticed when using sewage effluent water to generate the steam.

The C_3 and C_4 olefin feed to a catalytic polymerization unit for producing polygasoline has been saturated with steam condensate from sewage effluent without noticeable changes in the catalyst life or quality of the gasoline. The process is a fixed, multibed solid phosphoric acid type of process.

For several years, chloride salts have been continuously washed from the feed-effluent heat exchange equipment of a hydrosulfurization unit with steam condensate. It was found that without this wash steam the heat exchanger tubes plug rapidly on the effluent side.

Table A-25 is a tabulation of the applications in which sewage effluent water has been used in process requirements. In maintaining bottom hole pressure of LPG products in salt cavern storage, there has been no evidence of algae problems. As a result of the ammonium nitrates present in the effluent there was a problem with the LPG products passing the copper strip corrosion test.

Reclaimed effluent has been used in electrical desalting of crude oil. It was found, however, that using effluent, the crude preheat exchange equipment fouled too rapidly. This problem was overcome by heating the water between 200 and 250 deg F.

ECONOMICS

In exchange for the sewage plant effluent, Cosden pays $14,400 per year towards operation of the municipal treatment plant. Additional treatment costs at the refinery are

Table A-24. TYPICAL REUSE APPLICATIONS OF STEAM PRODUCED FROM TREATED MUNICIPAL EFFLUENT AT COSDEN OIL, BIG SPRING, TEXAS

- Steam stripping of atmospheric crude oil distillation sidecut streams.
- Vacuum jet requirements for flash separation between gas oil and asphalt.
- Steam stripping of FCC fractionator side streams.
- Steam stripping of FCC catalyst (both regenerated and spent).
- Steam stripping of boiler feed water.
- Steam-air decoking of catalyst:
  - Cobalt-moly type hydrogeneration
  - Activated carbon
  - Palladium
- Steam-air decoking of furnace tubes.
- Fuel oil atomizing.
- Ethylbenzene dehydrogenation reaction diluent.
- Steam required to create vacuum for styrene monomer distillation.
- Heating process streams in tubular exchanger equipment.

Table A-25. REUSE APPLICATIONS OF PROCESS WATER PRODUCED FROM TREATED MUNICIPAL EFFLUENT AT COSDEN OIL, BIG SPRING, TEXAS

- Maintenance of bottom hole pressure for salt well storage of light hydrocarbons.
- Crude oil desalter water requirements.

listed in Table A-26 and compared to the procurement and treatment costs of water from Lake Thomas.

Table A-26. REPORTED 1967 COSTS OF WATER FOR BOILER FEED AT COSDEN OIL, BIG SPRING, TEXAS

Item	Source	
	Municipal Sewage Effluent Water	Raw Lake Water
Capital investment	$300,000	$300,000
Capacity	825 gpm	825 gpm
	$/M gal.	$/M gal.
Water costs	0.045	0.185
Chemical costs:		
Oxygen scavenging agency @ $100/ton	0.0028	0.0029
Lime @ $20/ton	0.0444	0.0157
Rock Salt @ $8/ton	0.0040	0.0040
Gypsum @ $18/ton	0.0184	--
Sludge conditioning agent @ $560/ton	0.0785	0.0457
Filming amine	--	0.0345
Utilities costs:		
Steam @ $0.30/1,000 BTU (15 psi gauge)*	0.4000	0.4000
Electrical power	0.0005	0.0005
Labor:	0.0671	0.0671
Supplies	0.0134	0.0134
Maintenance:	0.0150	0.0150
Amortization:**	0.0921	0.0921
Total cost at design rate:	0.7870	0.8797

*This heat is actually utilized as boiler preheat.

**Over ten years with alternate value of money at 6% compounded annually.

SCS Engineers has calculated the total cost of effluent treatment by the municipal plant at $343/MG.

DENTON, TEXAS

INTRODUCTION

The city of Denton initiated reuse of its municipal wastewater effluent in 1972 for makeup water to cooling towers of the city power generating station. The effluent was of variable quality. As a result major difficulties were experienced by the power plant during the summer of 1972. The city reports that operations during the spring of 1973 improved greatly, however, others presently considering reuse of effluent for cooling tower makeup can benefit from Denton's initial experiences. The reader is directed to the chapter on industrial reuse in this report which concludes that unless the municipal sewage treatment plant produces a superior effluent, e.g., BOD and SS below 5-10 mg/l, additional clarification should be provided for further removal of organics, nutrients, and suspended solids prior to use in recirculating cooling towers.

The city of Denton initially attempted, without further clarification, to use, for cooling water makeup, an average secondary treated effluent from a plant on the verge of being overloaded. It could not be successfully done. Massive fouling of heat exchange systems by bacterial growths occurred, significantly reducing power generation efficiencies and increasing maintenance costs.

MUNICIPAL TREATMENT PROCESSES

The city sewage treatment plant has reached its design flow of 6 mgd, with maximum flow rates up to 10 mgd. A plant expansion is being planned since the existing facility is on the verge of being overloaded. Raw sewage is only one percent industrial waste, primarily blood from a packing house and heavy metals from a plating operation.

Figure A-22 schematically illustrates the treatment processes at the sewage treatment plant and the power generation station. Incoming raw sewage is screened, grit removed, and settled in three primary clarifiers, 58 ft diameter x 7 ft deep. Primary effluent flows to five aeration tanks

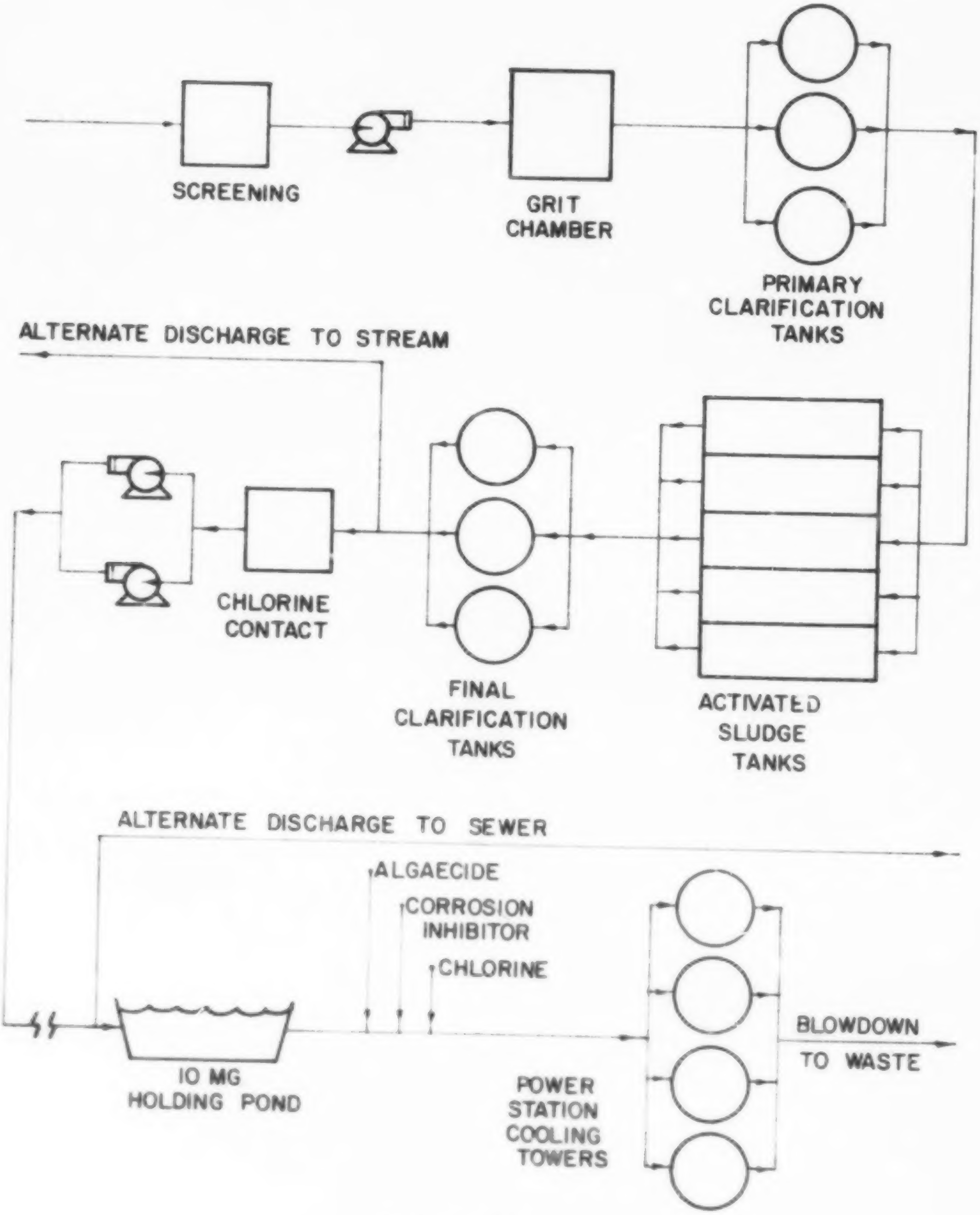
SCREENING
GRIT CHAMBER
PRIMARY CLARIFICATION TANKS
ALTERNATE DISCHARGE TO STREAM
CHLORINE CONTACT
FINAL CLARIFICATION TANKS
ACTIVATED SLUDGE TANKS
ALTERNATE DISCHARGE TO SEWER
ALGAECIDE
CORROSION INHIBITOR
CHLORINE
BLOWDOWN TO WASTE
10 MG HOLDING POND
POWER STATION COOLING TOWERS

FIGURE A-22
MUNICIPAL WASTE WATER TREATMENT FACILITY
AND POWER STATION REUSE
DENTON, TEXAS

which may be alternatively operated in a conventional activated sludge manner, step aeration, or with sludge reaeration. The tanks each measure 29 ft x 150 ft x 15 ft deep. Operating parameters are as follows:

- 4 hour detention
- 2,500 to 3,000 mg/1 MLSS
- 40 to 45 percent sludge recirculation

The three secondary clarifiers are 70 ft diameter x 12 ft deep with a design overflow rate of 520 gpd/sq ft. Chlorine contact is for 30 minutes at design flow of 6 mgd.

Sludge is anaerobically digested and treated by the Zimpro process.

An average 4.5 mgd of final effluent is gravity discharged from the chlorine contact tank to an adjacent creek. The remaining 1.5 mgd is pumped approximately 2 miles through an 18 inch diameter steel pipe, terminating in a 10 MG capacity unlined storage pond adjacent to the power plant.

Reported quality of the final effluent is shown in Table A-27.

Table A-27. AVERAGE MUNICIPAL EFFLUENT CHARACTERISTICS AT DENTON, TEXAS

Characteristic	Concentration (mg/1)
BOD	30
SS	38
TDS	127
Cl	70
pH	7.2
MPN	16,000

The effluent characteristics shown in Table A-25 are reported to be superior to the quality of the reclaimed water in the 10 MG holding pond. Apparently the effluent sometimes becomes septic in the 2 mile force main enroute to the pond, since dark, odorous discharge into the pond is reported by power plant personnel.

REUSE PRACTICES

The municipal steam electric generating station which attempted to use the effluent for approximately 3 months is 110 Mw in size. The steam station pumped the effluent out of the 10 MG holding pond direct to the cooling towers. Chlorine, algicides and scale inhibitor are added to the cooling tower recirculating water. While effluent was used, dosages of these chemicals were doubled or quadrupled, over normal fresh water dosages, but great difficulties were still experienced due to rapid fouling of condenser tubes. Suspended solids, organics and nutrients in the effluent were at too high a level. Unlike some other cooling water applications of reclaimed wastewater, the TDS level at Denton is relatively low at 127 mg/1.

It appears to SCS Engineers that the city of Denton reuse problems can only be solved by greatly improved treatment facilities at the wastewater treatment plant or additional treatment at the power plant to reduce suspended solids, organics and nutrients.

ECONOMICS

The economics of the Denton reuse program are unresolved since the effluent was not of suitable quality. The sewage treatment plant cost $0.5 million to construct in 1964 and an additional $1.2 million to expand in 1968. Operating costs in 1971 were $174,000. Including amortization of capital investment, treatment costs average approximately $168/MG. Operating costs alone comprise $80/MG. Pumping costs to transport the effluent 2 miles to the steam station are estimated at $20/MG additional.

The power station reports that cost of its chemical treatment for cooling water is $40 to $50/MG for fresh water, and $80 to $100/MG during their attempt to use the effluent during their attempt to use the effluent during 1972. These costs covered purchase of chlorine, acid, algicides, corrosion inhibitor, etc.

LUBBOCK, TEXAS

INTRODUCTION

The city of Lubbock, Texas supplies reclaimed water for industrial and agricultural reuse. Out of 14 mgd of treated effluent generated in an average day, approximately 20 percent is sold to Southwestern Public Service Company for use as cooling water and boiler feed water makeup, and the remaining 80 percent is used by local farmers for irrigation.

Lubbock, Texas illustrates the advantages to both municipality and industry of the utilization of reclaimed municipal wastewater. Southwestern Public Service Company is heavily dependent on the renovated water supply, which it requires to reach optimal operating capacity. Economic advantages are reflected in lower water costs to the power company and greater revenues to the city from reclaimed water sales.

MUNICIPAL TREATMENT PROCESSES

The municipal treatment system at Lubbock consists of three interconnected treatment plants located on one site southeast of the city and one located northwest of the city. Two of the southeast plants are trickling filter plants with a combined capacity of approximately 14 mgd and one is an activated sludge plant capable of treating 12 mgd. Only the activated sludge plant supplies renovated water for industrial reuse and the trickling filter effluent is used solely for irrigation. The northwest treatment plant is a contact stabilization plant with a rated capacity of 0.75 mgd. Chlorinated effluent is pumped to Texas Tech University farm for irrigation. The remainder of this report will be concerned primarily with the activated sludge plant and Southwestern Public Service Company's reclaimed water treatment and reuse system.

Of the 6 to 7 mgd treated by the activated sludge plant, approximately 20 percent is industrial waste. The four major industrial wastes are: cotton seed oil and hulls, packing house grease and blood, dairy whey, and various heavy metals from plating plants. These industrial components have adversely affected the efficiency of the treatment plant on past occasions as follows: (1) Grease and oil clogs piping and machinery and inhibits settling. (2) Blood and whey have extremely high BOD's (100,000 mg/l and 42,000 mg/l respectively), thus surge loads can significantly increase effluent BOD's. (3) Chromium, arsenic and other heavy metals, even in low concentrations, can be toxic to activated sludge bacteria and upset the process.

Figure A-23 schematically illustrates the activated sludge plant. Primary treatment for the activated sludge plant consists of screening and grit removal followed by gravity settling. Secondary activated sludge treatment involves conventional spiral flow with 6 hour detention at 12 mgd design flow with an MLSS concentration of 2,000 mg/l. Recycled sludge (30 to 50 percent recirculation rate) is treated with 3 to 5 mg/l chlorine for control of sludge bulking. In the aeration tanks, an average 1,680 cu ft of air is supplied per pound of BOD removed. Two gravity, circular secondary clarifiers with 580 gpd/sq ft overflow rates are employed for final settling. Reclaimed effluent for use by Southwestern Public Service Company is then chlorinated at 4 to 10 mg/l and pumped to the power plant about 3 miles away. Irrigation water is stored in three lagoons with a total capacity of 30 million gallons. Solids handling involves conventional anaerobic digestion followed by sludge drying beds.

Problems with the activated sludge operations, aside from those connected with industrial wastes previously discussed, concern overloading of the digesters causing a poor quality supernatant that is discharged to the older trickling filter plant, and prolific algae growth in the aeration tanks which hinders settling. Effluent characteristics from the activated sludge plant are listed in Table A-28.

USER TREATMENT PROCESSES

The reclaimed water is given further treatment by Southwestern Public Service Company prior to reuse as illustrated in Figure A-24. The effluent is discharged into two cold lime clarifiers for removal of solids and phosphates. Lime is fed at a rate of 3 lbs/1,000 gal and alum at 0.2 lbs/1,000 gal. Sulfuric acid is added to lower the pH to neutral. Next, storage is provided in a 6 MG concrete-lined lagoon, to meet irregular flow demands and to serve as an emergency reserve, prior to use in the cooling towers. Further extensive treatment is given to 30,000 gpd for use as boiler feed water makeup. After the cold lime treatment and pH adjustment, this water is fed to a reverse osmosis

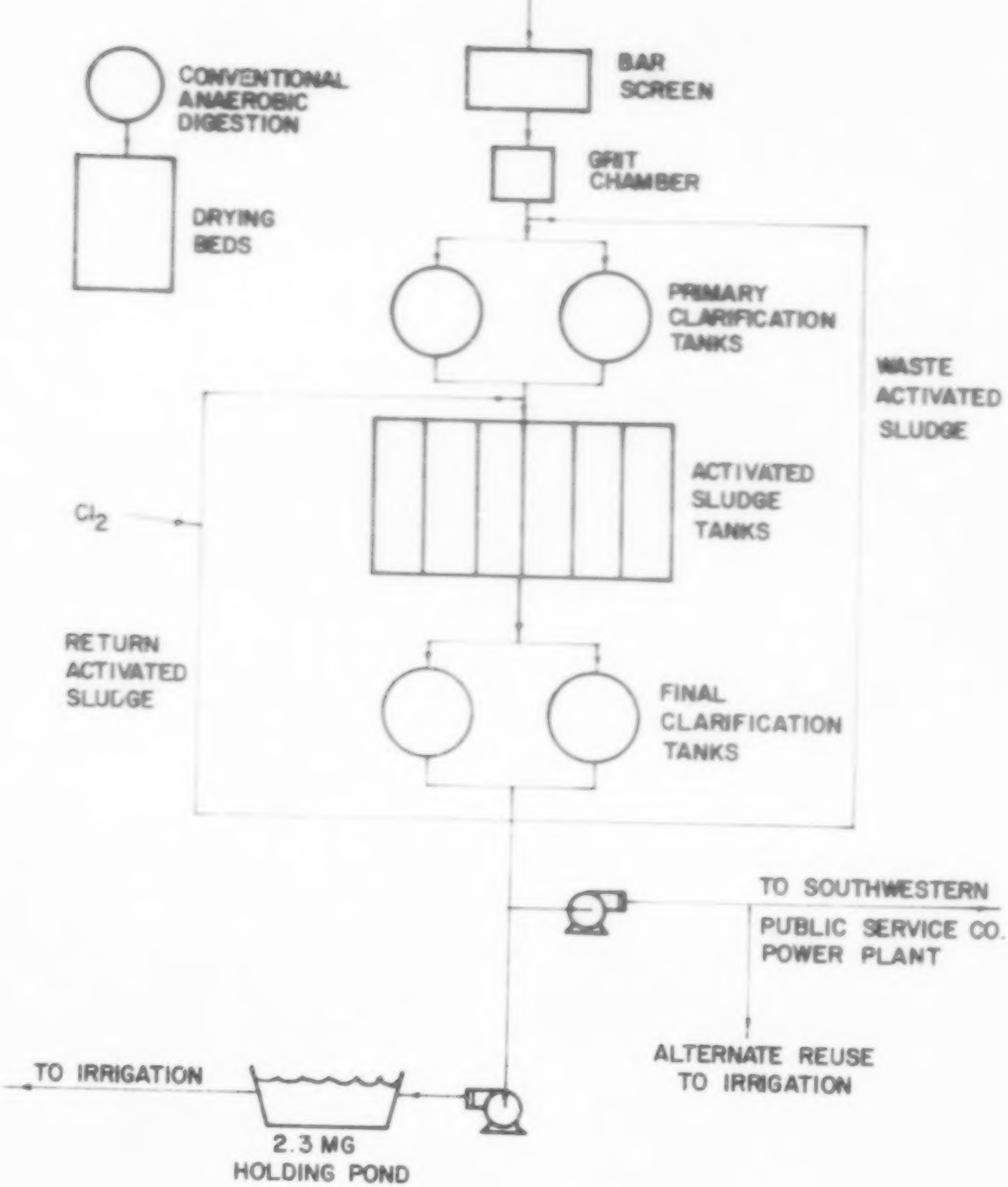
CONVENTIONAL ANAEROBIC DIGESTION
DRYING BEDS
BAR SCREEN
GRIT CHAMBER
PRIMARY CLARIFICATION TANKS
WASTE ACTIVATED SLUDGE
ACTIVATED SLUDGE TANKS
Cl_2
RETURN ACTIVATED SLUDGE
FINAL CLARIFICATION TANKS
TO SOUTHWESTERN PUBLIC SERVICE CO. POWER PLANT
ALTERNATE REUSE TO IRRIGATION
TO IRRIGATION
2.3 MG HOLDING POND

FIGURE A-23
MUNICIPAL WASTE WATER TREATMENT FACILITY
LUBBOCK, TEXAS

Table A-28. AVERAGE MUNICIPAL EFFLUENT CHARACTERISTICS FROM ACTIVATED SLUDGE PLANT AT LUBBOCK, TEXAS

Characteristic	Concentration (mg/l)	Characteristic	Concentration (mg/l)
BOD	18	Total hardness	240
SS	20	Ca	145
TDS	1,650	SiO_2	11.5
Na	450	PO_4	35
Cl	460	SO_4	250
P-Alkalinity	0	Chlorine residual	2
M-Alkalinity	250	pH	7.8

unit that removes 85 percent of the total dissolved solids while wasting 30 percent of the flow as concentrated brine solution. The R.O. unit has completed over one year of operation, but Southwestern believes it would be premature to make any accurate performance evaluation of the cellulose acetate membranes. Following R.O., total demineralization is achieved by passage through successive cation exchange, weak base anion exchange, and strong base anion exchange units, followed by a mixed bed polishing unit. Due to the salt removal by the R.O. unit, the demineralization train has been operated for as long as 6 months between regenerations. Effluent from the treatment system exceeds the quality of distilled water for direct use in the boilers. Table A-29 shows typical quality characteristics of the reclaimed water at various stages of treatment.

REUSE PRACTICES

An average of 2 to 3.5 mgd of reclaimed water satisfies the entire water demand of the Southwestern Public Service Company for cooling water and boiler feed water makeup in their 250 Mw power generation plant. Fresh water is available from the city in the event of failure of the reclaimed water system, however, the 0.7 mgd available from the city would be insufficient to run the power plant at rated capacity.

Overall, the use of reclaimed water for cooling and boiler feed makeup water has been successful at Southwestern Public Service Company. The Company's confidence in this renovated water supply is reflected by the current construction of new boiler facilities to increase the power generating capacity from 250 Mw to 500 Mw, and proportionately increase the use of reclaimed water. Several minor problems

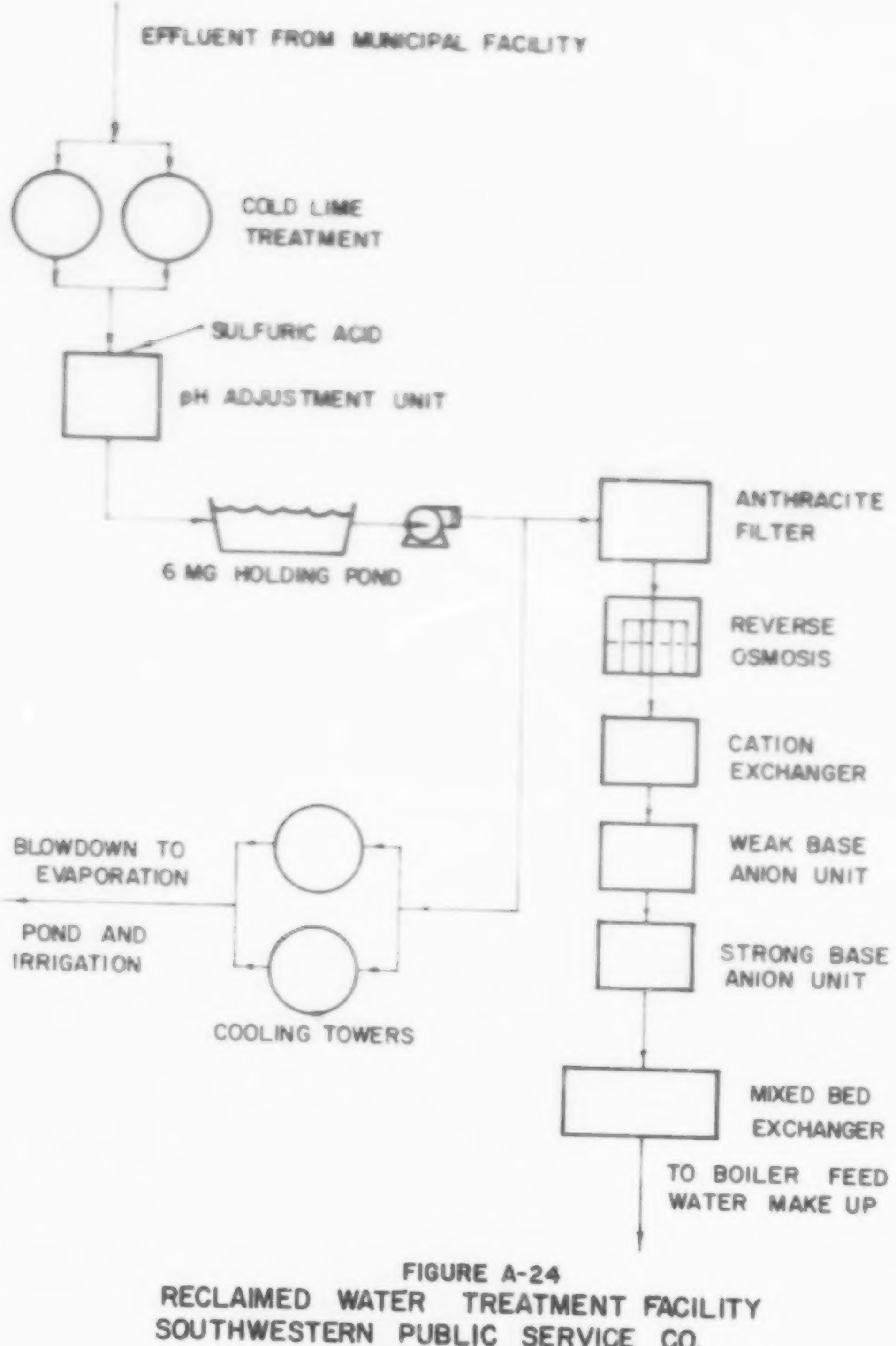
EFFLUENT FROM MUNICIPAL FACILITY
COLD LIME TREATMENT
SULFURIC ACID
pH ADJUSTMENT UNIT
6 MG HOLDING POND
ANTHRACITE FILTER
REVERSE OSMOSIS
CATION EXCHANGER
WEAK BASE ANION UNIT
STRONG BASE ANION UNIT
MIXED BED EXCHANGER
TO BOILER FEED WATER MAKE UP
BLOWDOWN TO EVAPORATION
POND AND IRRIGATION
COOLING TOWERS

FIGURE A-24
RECLAIMED WATER TREATMENT FACILITY
SOUTHWESTERN PUBLIC SERVICE CO.
LUBBOCK, TEXAS

Table A-29. AVERAGE WATER CHARACTERISTICS AT VARIOUS STAGES OF TREATMENT FOR REUSE AT SOUTHWESTERN PUBLIC SERVICE COMPANY, LUBBOCK, TEXAS

	State of Tertiary Treatment				
Characteristic (mg/1)	Power Plant Influent	Cold-Lime Treater Effluent	R.O. Unit Influent	R.O. Unit Effluent	Boiler Feed Influent
P-Alkalinity	0	158	--	--	0
M-Alkalinity	250	220	--	8	0
OH	--	96	--	--	0
Total Hardness	240	240	234	8	0
Ca	145	214	180	6	.02
SiO_2	11.5	1.5	1.5	0.6	0
PO_4	35	1.5	1.5	0.5	0
SO_4	250	250	380	10	0
Cl	358	358	354	62	0
pH	7.8	10.6	5.6	5.5	7.0
Chlorine Residual	2	0	0	0	0
Conductivity, Mmho	--	0	1,760	180	0
TDS	--	--	1,130	115	0

were reported in the treatment and reuse of the municipal effluent. Prolific bacterial growth in the 6 MG storage lagoon following cold lime treatment produces acids through biological activity and organics breakdown. This acid upsets the pH equilibrium in the cooling towers and may force treatment with chlorine to kill the microorganisms. More frequent cleansing of the R.O. unit membrane is necessary because of the higher TDS concentration of the reclaimed water than would be expected using fresh water. The problem of cooling tower blowdown disposal with its high concentration of dissolved salts, is solved by storage and evaporation in an unlined pond which also serves as a water supply storage for seasonal irrigation by a local farmer.

Reclaimed water for irrigation is stored in three lagoons with a total capacity of 30 MG. One large grower receives the majority of the water free of charge in exchange for disposing of all the effluent, except that used at the power plant, on his 2,500 acres of land. Crops irrigated with reclaimed wastewater include: cotton, sorghum, alfalfa, winter wheat, and pasture grasses.

ECONOMICS

Both the city of Lubbock, and the Southwestern Public Service Company gain economic advantages through the treatment and reuse of renovated water. The power company pays a total cost of 14.4c/1,000 gal for the reclaimed water. Of this sum, 11.9 goes to the city of Lubbock and pays the power company's prorated share of the operating cost of the 12 mgd capacity activated sludge plant. The remaining 2.5c is paid as a reimbursement to the large irrigation user who has a legal right to the water until 1990 for his irrigation program. The large irrigation user receives the water free in exchange for disposing of all the effluent on his land, allowing none to escape to surface waters.

Total costs to Southwestern Public Service Company for reclaimed water purchase and treatment are shown in Table A-30.

The power company has no discharge permit but currently sells its cooling tower blowdown water to a local farmer for irrigation at 1c/1,000 gal. Evaporation ponds are used for ultimate disposal if the farmer does not utilize the entire flow.

Table A-30. REPORTED COSTS OF WATER FOR REUSE AT SOUTHWESTERN PUBLIC SERVICE COMPANY, LUBBOCK, TEXAS

Item	Cost (¢/1,000 gal)
Paid to city of Lubbock	11.9
Paid to other owners	2.5
Operating cost of tertiary treatment plant (including capital amortization)	16.0
Total reuse cost	30.4

ODESSA, TEXAS

INTRODUCTION

The El Paso Products Company of Odessa, Texas, is currently using reclaimed water from the Odessa Municipal Sewage Treatment Plant for makeup water to cooling towers and low pressure boilers. This water reclamation and reuse operation is of economic value to both city and industry. El Paso Products receives an inexpensive, reliable, and continuous water supply while the city of Odessa receives sufficient revenues to operate the sewage treatment plant and also partial funding of plant expansions and improvements.

MUNICIPAL TREATMENT PROCESSES

The sewage treatment plant at Odessa provides secondary treatment to an average of 6.5 mgd of which 99 percent is domestic sewage and 1 percent is industrial waste, primarily from a plating operation. Primary treatment units consist of screening, grit removal, grease removal, and primary clarification. Primary effluent is stored in an aerated equalization tank of 1 MG capacity to provide steady flow into the aeration tanks.

Secondary activated sludge treatment takes place in three tanks with conventional spiral flow, MLSS concentrations of 1,100 to 1,400 mg/l and 3.5 hour detention time. Clarification is performed in three final circular clarifiers, two of 70 ft diameter and 11 ft depth and a third with 90 ft diameter and a depth of 13 ft. Chlorination is done in a contact basin with 30 minute detention. Pumps transport reclaimed water to either El Paso Products' 15 MG lagoon or storage ponds for irrigation. Figure A-25 shows a schematic of the municipal treatment process.

Reported quality characteristics of the treated wastewater are:

- BOD - 10 mg/l
- SS - 13 mg/l
- TDS - 1,300 mg/l

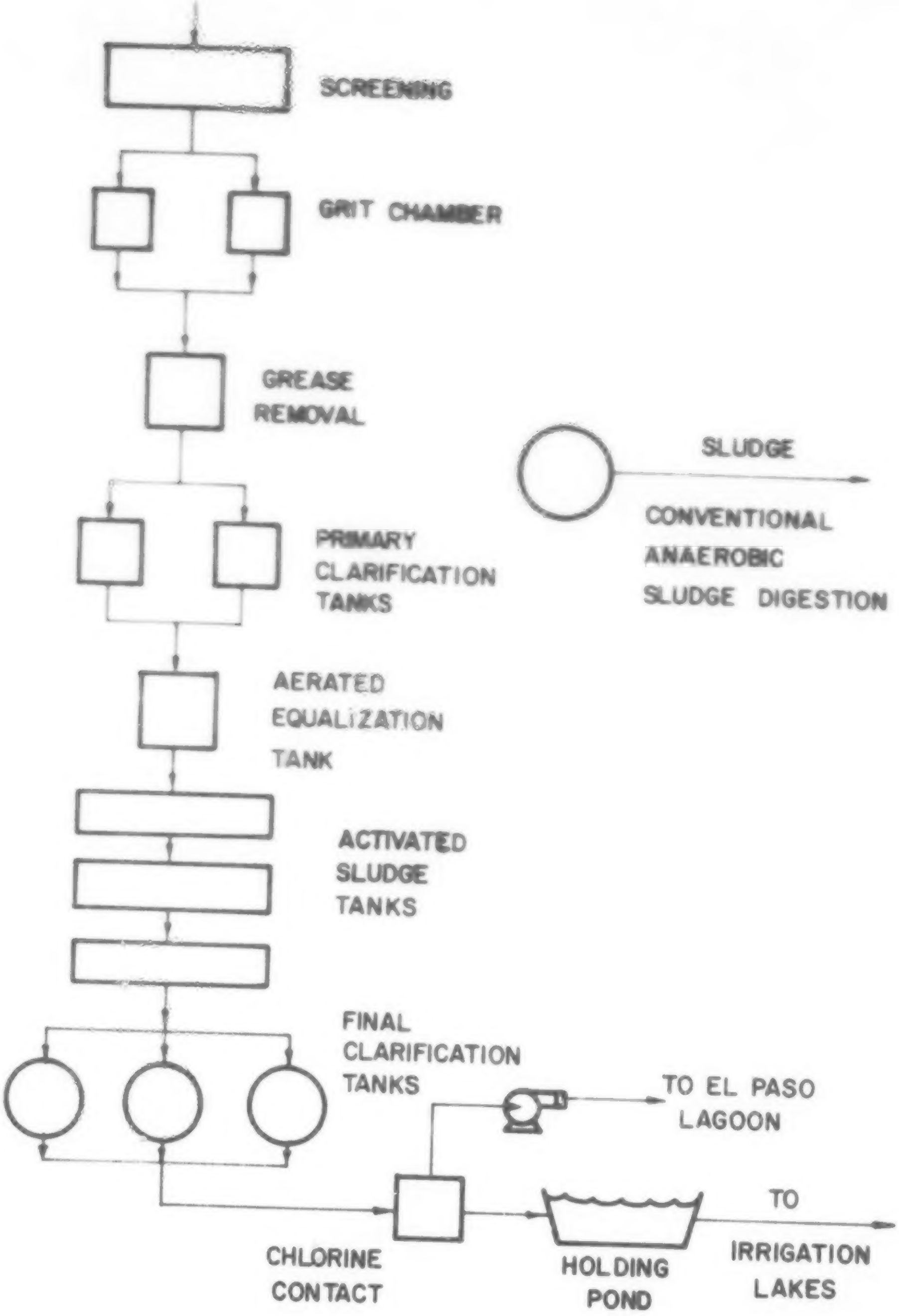
SCREENING
GRIT CHAMBER
GREASE REMOVAL
SLUDGE
CONVENTIONAL ANAEROBIC SLUDGE DIGESTION
PRIMARY CLARIFICATION TANKS
AERATED EQUALIZATION TANK
ACTIVATED SLUDGE TANKS
FINAL CLARIFICATION TANKS
TO EL PASO LAGOON
TO IRRIGATION LAKES
CHLORINE CONTACT
HOLDING POND

FIGURE A-25
MUNICIPAL WASTE WATER TREATMENT FACILITY
ODESSA, TEXAS

- Chlorides - 250 mg/l
- Coliform - 6×10^5/100 ml
- pH - 7.4
- Hardness - 240 mg/l
- Total P - 44 mg/l
- Total N - 18 mg/l

Occasionally high concentrations of chromate from a plating operation must be bypassed to the irrigation lakes.

USER TREATMENT PROCESSES

The El Paso Products Company at Odessa, Texas, is a large chemical manufacturing plant requiring 7 mgd to satisfy its water demand. Approximately 5.5 mgd is supplied by treated sewage effluent with the remainder coming from company-owned wells.

As shown in Figure A-26 El Paso Products operates a sophisticated water treatment system to give further treatment to the effluent from the sewage plant and to well-water supplies.

El Paso's holding lagoon is an unlined pond with a capacity of 15 MG and is utilized for eliminating surges and for storing fire demand and utility water. Water from the holding lagoon is pumped to a cold-lime treater, the essential purpose of which is to remove phosphates and suspended solids. Some hardness and silica are removed, but the quantity is considerably less than the theoretical amount of which a cold-lime treater is capable. The reason for the underrated efficiency is believed to be due to ammonia oxidizing to nitrate, followed by reaction with calcium bicarbonate to produce calcium nitrate and carbon dioxide. These processes reduce the amount of calcium bicarbonate hardness that can be removed by lime treatment. Treatment in the lime treater is accomplished with hydrated lime fed at 150 mg/l and a cationic polyelectrolyte at 2 mg/l.

The effluent from the cold-lime treater is recarbonated to convert carbonate and hydroxyl ions to the soluble bicarbonate in the subsequent water-conditioning equipment. Recarbonation is accomplished with waste carbon dioxide from El Paso's ammonia plant. The recarbonation system has bottled-gas and inert-gas generators on emergency standby. Sludge from the cold-lime treater is thickened in an old hot-lime treater shell. The overflow is returned to the treater and the bottom sediment is sent to the waste disposal area.

After recarbonation the water contains suspended floc and must be filtered before further use. This filtration is

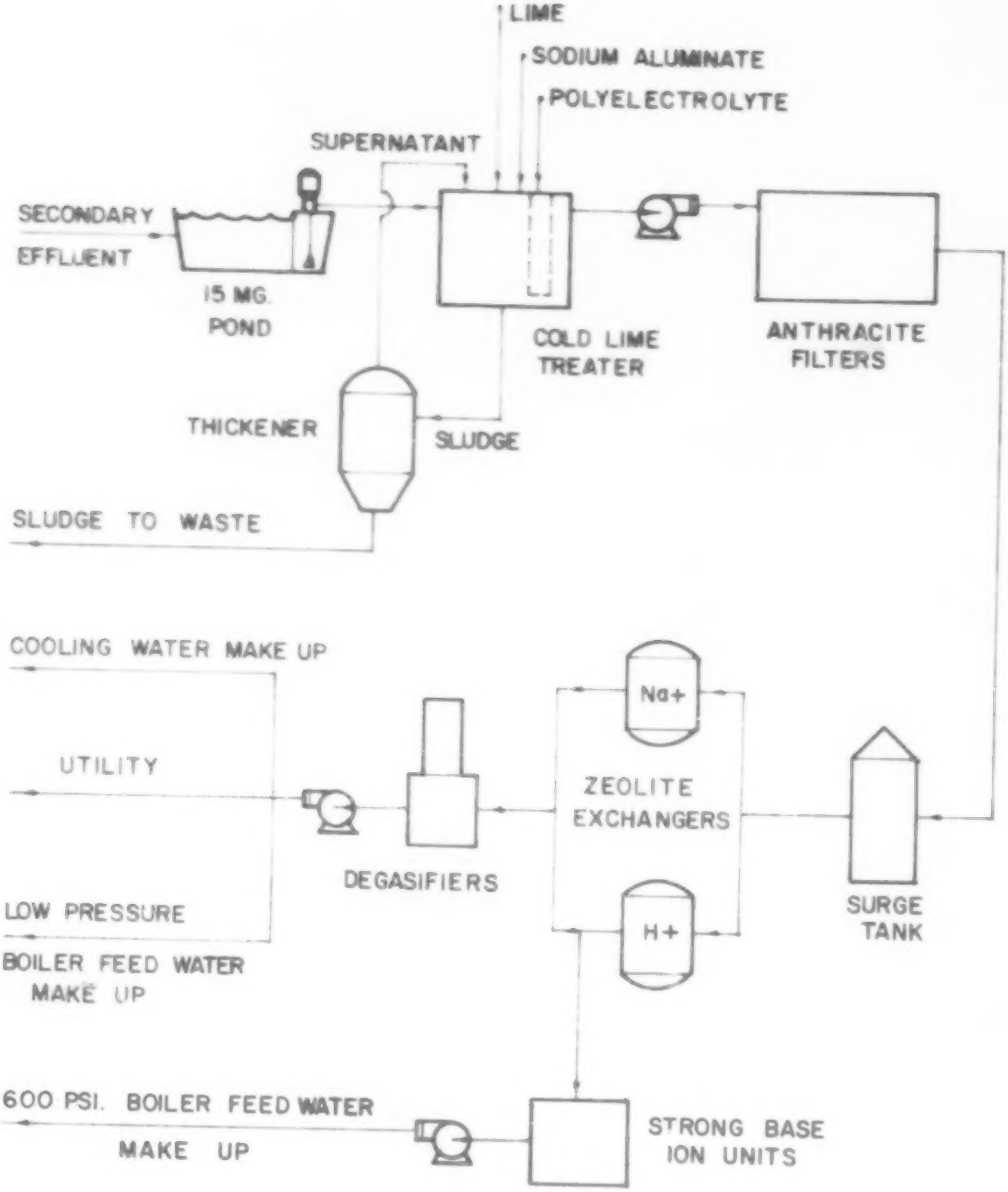
LIME
SODIUM ALUMINATE
POLYELECTROLYTE
SUPERNATANT
SECONDARY EFFLUENT
15 MG. POND
COLD LIME TREATER
ANTHRACITE FILTERS
THICKENER
SLUDGE
SLUDGE TO WASTE
COOLING WATER MAKE UP
UTILITY
LOW PRESSURE BOILER FEED WATER MAKE UP
Na+
ZEOLITE EXCHANGERS
H+
DEGASIFIERS
SURGE TANK
600 PSI. BOILER FEED WATER MAKE UP
STRONG BASE ION UNITS

FIGURE A-26
RECLAIMED WATER TREATMENT FACILITY
EL PASO PRODUCTS COMPANY
ODESSA, TEXAS

accomplished in pressure-type filters utilizing sized anthracite coal for the filtering media. Backwash water from the filters is reclaimed in a closed backwash system consisting of a primary surge tank, a clarifier, two pressure-type filters, and a final surge tank. The backwash water is continually reused, with fresh water being added to replace that which is lost through clarifier blowdown.

The filtered water is stored in a 50,000-barrel capacity surge tank which enables the lime treater to operate at a steady rate even though water demands in the industrial complex fluctuate between day and night conditions.

Water is taken from the surge tank and split into two streams, one of which goes to sodium zeolite exchangers and the other to hydrogen zeolite exchangers. After softening, the streams are blended together and sent to degasifiers where the carbon dioxide formed by blending the streams is stripped from the water with the use of air. The degasifier basins contain level controllers that regulate the flow of sodium zeolite-treated water in accordance with the demand for total split-stream water, with the flow of hydrogen zeolite-treated water being proportional to the sodium flow. An operator determines, by analysis, the ratio of each stream needed to obtain the desired total alkalinity of the blended stream and sets this ratio into the ratio controllers.

Regeneration of the exchangers is accomplished with sodium chloride in the sodium units and hydrochloric acid in the hydrogen units. Backwash water for the ion exchangers is taken from and returned to the closed backwash system. Rinse from the sodium units goes to the process sewer within the complex, whereas rinse from the hydrogen units goes to a waste acid surge tank in the waste disposal area. At this point, El Paso incorporates another in-plant reuse plan by recovering the last third of the rinse from both the sodium and hydrogen exchangers and returning it to the 50,000-barrel surge tank.

Tables A-31 and A-32 list typical quality attainments in the user treatment processes and representative parameters for the various reuse systems.

REUSE PRACTICES

Split-stream water is used for cooling tower blowdown and as makeup to the low pressure (175 psi to 250 psi) boilers. A small stream of the hydrogen zeolite water is demineralized in strong-base anion units for high pressure (600 psi) boiler makeup.

Table A-31. AVERAGE WATER CHARACTERISTICS AT VARIOUS STAGES OF TREATMENT FOR REUSE AT EL PASO PRODUCTS COMPANY, ODESSA, TEXAS

Characteristic (mg/l)	Stage of Tertiary Treatment			
	Sewage Effluent	Cold-Lime Effluent	Recarbonator Effluent	Split Stream
P alkalinity	0	85	0	0
M alkalinity	137	159	159	64
Total hardness	240	158	163	0
Ca	51	47	48	0
Mg	10	10	10	0
Cl	250	146	151	156
SO_4	101	97	101	97
Na	92	78	92	117
SIO_2	19	19	19	19
PO_4	40	4	-	-
Conductivity, Mmho	1,012	935	1,020	925
pH	7.4	10.2	7.9	7.1

Table A-32. TYPICAL QUALITY CHARACTERISTICS IN TERTIARY TREATMENT AND REUSE UNITS AT EL PASO PRODUCTS COMPANY, ODESSA, TEXAS

Unit and characteristic	Conc.
Lime Treater	
Lime (2P-M)*, mg/l	20-50
Sludge volume (15 min settling), %	20
Algae control	as required
Recarbonator	
P alkalinity (controlled by CO_2)	0
Sodium Units	
Hardness, mg/l as $CaCO_3$	5 max.
Hydrogen Units	
Free mineral acidity, mg/l	200-375
Hardness, mg/l as $CaCO_3$	0
Split-Stream Blend	
M alkalinity, mg/l as $CaCO_3$	40-60
Hardness, mg/l as $CaCO_3$	0 to trace
600 psi Boilers	
Dissolved solids as conductivity, Mmho	1,000
Phosphate, mg/l	40-60
Sodium sulfite, mg/l	25-35
Antifoam	as required
Negative hardness, mg/l	-2 to -5
Causticity, mg/l as OH	50-100
Silica, mg/l	50
Steam and Condensate	
pH	7.5 to 8.0
Cooling Tower	
M alkalinity, mg/l as $CaCO_3$	80-100
P alkalinity, mg/l as $CaCO_3$	0
Conductivity, Mmho	7,000 ± 250
Orthophosphate, mg/l	20
Chromate, mg/l	12-15
Filterable solids, mg/l	20
Dispersant, gpd	1
pH	6.4 to 6.8
SiO_2, mg/l	150
Total plate count, bacteria/ml	3.0×10^6
Corrosion probe, MPY	2.0
Bactericides	
Quaternary ammonium compounds, nitrogen-based compounds, pentachlorophenate, trichlophenate, peracetic acid, and chlorine.	

Cooling towers are of the recirculating counterflow type and utilize a concentrated solution of zinc and chromate for corrosion inhibition, the major ingredient of which is zinc salt. The inhibitor functions as a true dicathodic polarization, and it contains no organics or phosphates that could serve as nutrients for bacterial growth.

ECONOMICS

In exchange for the effluent from the Odessa treatment plant, El Paso Products pays virtually all the operating expenses for the municipal plant. Last year these expenses amounted to approximately $250,000 or 12.5¢/1,000 gal received. In comparison, raw water taken from the public supply would cost approximately 50¢/1,000 gal with zeolite softening and degasification still being necessary. In addition to operating costs, El Paso Products paid the $1,000,000 construction cost of the original secondary facility at the City of Odessa plant and for the addition, in 1965, of a third clarifier, blower, and spargers at a cost of approximately $100,000.

Table A-33 is a breakdown of water treatment costs at the El Paso Products plant during the period January 1970 to September 1970, which is representative of current expenditures.

Table A-33. AVERAGE TREATMENT COSTS FOR REUSE AT EL PASO PRODUCTS COMPANY, ODESSA, TEXAS

ITEM	COSTS	
	$	¢/1000 gal*
Raw Water		
Sewage effluent	140,111	12.55
Well water	31,635	
	171,746	
Chemicals		18.72
Lime (150 mg/l)	25,128	1.84
Coagulant (sodium aluminate, 15 mg/l) (polymer, 2 mg/l)	14,786	1.08
Biocide	6,031	0.44
Acid	160,568	11.73
Brine	38,305	2.80
Sodium softener cleaning	2,888	0.21
Resin, filter media	8,476	0.62
Utilities		14.94
Power	43,081	3.15
Waste water disposal	161,407	11.79
Operations		11.66
Labor	103,942	7.59
Supervision and engineering	7,308	0.53
Expenses	28,879	2.11
Administrative overhead	19,612	1.43
Maintenance	133,900	9.78
	Total	67.65

*Based on 1,368.6 MG total influent
(Waste water 1,203.5 MG and well water 165.1 MG)

WALLA WALLA, WASHINGTON

INTRODUCTION

Farmers in Walla Walla have utilized reclaimed sewage effluent for irrigation since the original treatment plant was constructed in 1929. A variety of crops, irrigated with renovated wastewater, are grown on a total of 1,650 acres of land including a 700 acre city-owned farm adjacent to the plant.

The Walla Walla reclamation program has several unique aspects. Truck crops for human consumption have been irrigated with sewage effluent for many years with approval of health authorities. During summer months over half the plant influent is industrial waste. Finally, an extensive spray irrigation system has been constructed to apply the effluent.

MUNICIPAL TREATMENT PROCESSES

The treatment facilities at Walla Walla are illustrated schematically in Figure A-27. Treatment is complicated by high industrial waste volumes generated by food canneries from mid-April through November. Different treatment and disposal is provided during these months than during the winter months when only the domestic raw sewage enters the plant.

The domestic system (as opposed to the industrial system) has a design capacity of approximately 7.5 mgd and consists of degriting and clarification followed by three high-rate trickling filters, 145 ft diameter and 4 ft deep, utilizing 2:1 recirculation ratios. The water then passes into three intermediate clarifiers, two with 60 ft diameters, and one rectangular with 45 ft x 90 ft dimensions. One standard rate, fixed nozzle, square trickling filter follows clarification and measures 220 ft square with 7 ft depth of rock media. Following the standard filter, chlorine is added to maintain a 0.5 mg/l residual into the final clarification tanks. The two final clarifiers are rectangular, measuring 35 ft x 140 ft and 35 ft x 80 ft, respectively. The treated

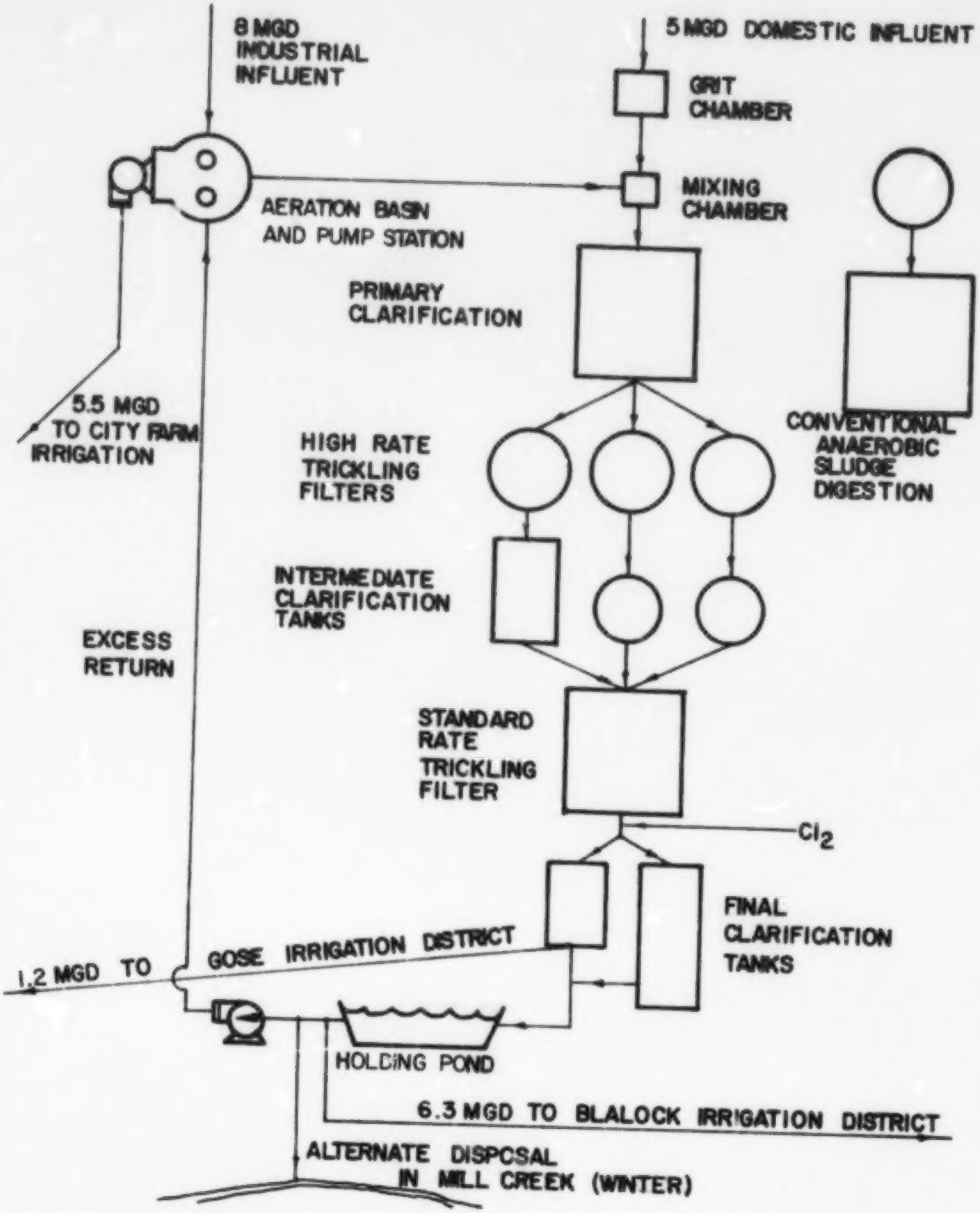
8 MGD INDUSTRIAL INFLUENT
5 MGD DOMESTIC INFLUENT
GRIT CHAMBER
MIXING CHAMBER
AERATION BASIN AND PUMP STATION
PRIMARY CLARIFICATION
5.5 MGD TO CITY FARM IRRIGATION
HIGH RATE TRICKLING FILTERS
CONVENTIONAL ANAEROBIC SLUDGE DIGESTION
INTERMEDIATE CLARIFICATION TANKS
EXCESS RETURN
STANDARD RATE TRICKLING FILTER
Cl_2
FINAL CLARIFICATION TANKS
1.2 MGD TO GOSE IRRIGATION DISTRICT
HOLDING POND
6.3 MGD TO BLALOCK IRRIGATION DISTRICT
ALTERNATE DISPOSAL IN MILL CREEK (WINTER)

FIGURE A-27
MUNICIPAL WASTE WATER TREATMENT FACILITY
WALLA WALLA, WASHINGTON

effluent is then stored in a surge lagoon from which 7.5 mgd flows by gravity to the Blalock and Gose Irrigation Districts. A pump station located at the lagoon returns excess water to the industrial wastewater treatment system when the effluent flow exceeds the irrigation demands of the two districts.

During the April-November period when canning is in progress, 0.0 to 3.0 mgd of the cannery waste is mixed with the domestic sewage and treated to supply the total 7.5 mgd needed by the Blalock and Gose Irrigation Districts. The remainder of the raw cannery waste (approximately 5.0 to 5.5 mgd) is stored temporarily in an aeration basin, treated with NaOH for pH control, and then is pumped directly to the 700 acre city farm for alfalfa irrigation. Alternative piping systems allow for intermediate treatment of certain industrial flows, by-passing primary treatment units, and entering the secondary process directly. The cannery wastewater is generally acidic in nature; therefore, NaOH is added in the aeration basin for pH control before the wastewater is pumped to the city farm.

The treatment system is flexible enough to satisfy all irrigation demands and yet provide secondary treatment to the largest water volume possible. During the non-growing season there is no canning activity, and the domestic sewage is given secondary treatment prior to release to an adjacent creek. During the growing season, all effluent from the plant, both domestic and industrial, is used for irrigation with no stream discharge. At this time of the year, Mill Creek is diverted for irrigation by upstream interests, and there is no water in the bed near the plant. During winter months, there is no industrial wastewater and domestic effluent is released to the now flowing receiving stream.

Effluent characteristics of the treated wastewater are as follows: BOD - 5 to 50 mg/l; SS - 4 to 23 mg/l; and pH - 6.5. The lower range of concentrations represent total domestic sewage effluent while the higher figures reflect considerable industrial wastewater contributions to the plant influent from canneries. Considering the seasonal reuse program, it is evident that the effluent of higher quality is released to the stream during winter months, while the poorer quality reclaimed wastewater is used for irrigation during the growing season.

REUSE PRACTICES

Referring again to Figure A-27, it is seen that the irrigation program in Walla Walla is comprised of two distinct systems. The city alfalfa farm of 700 acres uses only aerated and neutralized industrial wastewater, while the Blalock and Gose Irrigation Districts use only effluent which has undergone complete secondary treatment.

The Blalock and Gose Irrigation Districts were using water from the creek contaminated with raw sewage at the turn of the century. When the sewage treatment plant was built in 1926, an agreement was reached between the city and the irrigators whereby water (treated or not) would be provided to the Blalock and Gose Districts at 9.48 and 1.77 cfs, respectively. The equivalent flow at this rate is 7.3 mgd. The new treatment plant is designed to provide 7.5 mgd of treated effluent to the districts. Blalock and Gose are divided into several hundred parcels of land, each containing only a few acres. Farmers supply their own irrigation pipe systems and irrigate carrots, onions, lettuce, spinach, radishes, turnips, beets, and asparagus with the reclaimed city effluent. Produce from these fields has been sold fresh as well as canned for years. The investigators were advised that the State Department of Ecology has not yet questioned the health hazards of human consumption of these vegetable crops. Neither has there been a lack of crop marketability. Knowledgeable local authorities, however, feel that this issue will be closely examined by public health authorities in the near future. It is interesting to note that, prior to completion of the 7.5 mgd secondary plant, untreated industrial waste was used to irrigate the District's fields. It is reported that clogging of pipes and sprinkler heads with slime and solids was a continual problem. Sludges present in the industrial waste stream sealed the surface of the ground and greatly reduced soil permeability. Subsequently, the sludge had to be manually removed from the furrows. The high chloride content of cannery wastewaters from processing peas caused some crops to turn yellow. High salt content was degrading to the agricultural soils, and odor problems were also significant under the old system.

The city, in 1972, completed a $1.6 million pump station and sprinkler irrigation system to irrigate the city alfalfa farm. The new system operated only six weeks using fresh water to test the system hydraulics and occasional industrial wastewater for trouble shooting. Full-scale operation is planned for 1973. Water is to be pumped from the 325,000 gal aeration basin to the fields by three 3,800 gpm pumps (one always on standby). Automatic controls regulate the wastewater flow through the piping network, which consists of two lead lines from the plant, each feeding into two main lines 1/4 mile apart. Laterials are spaced 80 ft apart off the main lines, and contain sprinkler heads at 60 ft intervals. By June 1973, industrial wastewater up to 6 mgd will be pumped through this irrigation system. Problems with clogging due to suspended matter and bacteriological and algal growth have been reduced during test runs by sprinkler head modifications. In essence, this system is an unusual land disposal system for industrial waste in that it will use Rain Bird type sprinklers and is municipally operated.

The system of wastewater reclamation and irrigational reuse provides advantages to the city and farmers alike. Farmers receive a large volume of irrigational water free of charge, without which their crop would be greatly reduced or totally eliminated. The city, on the other hand, is saved from the problems and costs of meeting stream standards for their industrial wastewater effluent.

ECONOMICS

The 7.25 mgd of treated effluent is provided to the Blalock and Gose Irrigation Districts at no charge under prior water rights agreements. Also, there is no inter-city transfer of funds between the alfalfa farm operation and the treatment plant, since the alfalfa farm is intended primarily for industrial waste disposal.

An analysis of cost/MG for treatment and disposal is given below:

Year constructed	1953	1962	1972
Capital cost, $ million	.173	.435	1.600
Construction cost index factor	2.09	1.61	1.00
1972 cost equivalent, $ million	.362	.700	1.600
Annual cost factor, 5.5 percent 25 year life	26,987	52,185	119,280

Total Annual Cost Factor	$198,452
Total Cperational Cost	90,367
Total Amortization & Operation Cost	$288,819

Annual Volume, MG	2,300
Total Cost, $/MG	126
Operational Cost Only, $/MG	39

The cost/MG of $39 for operation only and $126 for capital recovery and operation are comparatively low. If the city treated its high-strength summer season wastes in a conventional manner and discharged direct to surface waters, the unit cost for treatment and disposal would be higher, based on costs experienced at other cities with a large percentage of cannery waste; e.g., Modesto, California.

APPENDIX B

QUESTIONNAIRE RESPONSE NUMBER			PRODUCER INFORMATION												
			INFLUENT			AVERAGE CHARACTERISTICS OF EFFLUENT TO REUSE									
		A5	B1a	B2b	B3	C1a	C1c	C2a	C2b	C2c	C2d	C2e	C2f	C2g	C2h
CODE NUMBER	MUNICIPAL PLANT LOCATION	YEAR REUSE BEGAN	TOTAL AVERAGE VOLUME, MGD	INDUSTRIAL WASTE %	SIGNIFICANT INDUSTRIAL WASTE TYPES	AVERAGE REUSE VOLUME, MGD	SEASON OF MAXIMUM REUSE	BOD, Mg/1	SS, Mg/1	TDS, Mg/1	Hd, Mg/1	CHLORIDES, Mg/1	pH, Mg/1	COLIFORMS, MPN	HEAVY METAL TYPES
AU-1	IRYMPLE, AUSTRALIA (Red Cliffs Sewer. Au.)	64	...	...	...	...	...	...	...	...	...	...	...	...	...
AU-2	MARYBOROUGH, VICTORIA, AUSTRALIA (Maryborough Sewer. Au.)	56	0.4	10	tanning	0.1	sum	35	30	...	...	10	7.6	...	...
AU-3	BHILL, VICTORIA, AUSTRALIA	40	0.1	0	none	0.1	none	9	26	...	350	...	7.3	...	...
AF-1	BULAWAYO, RHODESIA, AFRICA	61	1.6	...	...	1.2	...	...	...	...	...	...	...	...	...
AF-2	PRETORIA, SOUTH AFRICA	53	20	10	brewery, dairy, metal	9.0	...	14	12	460	...	60	7.5	0	...
AF-3	WINDHOEK, SOUTH WEST AFRICA	68	2.25	10	brewery, dairy, meat	0.7	spr sum	0.5	0	650	110	91	7.8	0	...
EN-1	BRISTOL, ENGLAND	65	3.5	...	...	3.5	...	7	7	700	...	100	7.5	...	Fe Ni Zn Pb
IS-1	HAIFA, ISRAEL	64	14.0	10	none	2.5	sum	70	75	1100	250	400	7.0	...	none
MX-1	MONTERREY, MEXICO	55	3.3	1	oil, chromate	2.7	...	17	10	510	...	26	7.1	...	none

SYMBOLS

QUALITY MONITORING DEVICES	
Cl_2	Cl_2 Residual Analiser
CON	Conductivity Meter
LAB	Laboratory Analysis
pH	pH Analizer
TURB	Turbidimeter
PURPOSE OF REUSE	
DOM	Domestic
FISH	Fish Habitation
IND	Industrial
IRR	Irrigation
GRD	Ground Water Recharge
REC	Recreation
END USE QUALITY CRITERIA	
BOD	Low BOD Required
B	Low Boron Required
Cl	Low Cl Required
DIS	Disinfection Required
DWQ	Drinking Water Quality
FD	Free of Debris
PO_4	Phosphate Removal
NH_3	Low NH_3 Required
OR	Odor Removal
pH	pH Adjustment Required
SHD	State Health Dept. Stds.
SS	Low SS Required
TDS	Low TDS Required
USPHS	U.S. Public Health Stds.

PRODUCER INFORMATION					USER INFORMATION					MUNICIPAL SEWAGE TREATMENT PLANT DESIGN INFORMATION						
REVENUE (Cost Data Appendix)		SYSTEM RELIABILITY														
D7	D8	E1	E2	E3	F6	F7	F9	F10	F8	G5	G6 & 7	G8b	G9	G10	QUESTIONNAIRE RESPONSE NUMBER	
UNIT CHARGES FOR EFFLUENT $/MG	TOTAL 1971 EFFLUENT SALES $1000	SUBSTANDARD EFFLUENT %	QUALITY MONITORING DEVICES	INTERRUPTION TOLERATION	PURPOSE OF REUSE	END USE QUALITY CRITERIA	ADDITIONAL TREATMENT	QUALITY SAFEGUARDS	SUPPLEMENTAL SUPPLY	DESIGN CAPACITY, MGD	TREATMENT PROCESSES	EFFLUENT STORAGE CAPACITY, MGD	EFFLUENT TRANSPORT DISTANCE, MILES	ALTERNATE DISPOSAL METHOD	COMMENTS	CODE NUMBER
...	...	...	...	...	IRR	...	...	...	...	...	PCL,TF,SCL, POL	...	...	...		AU-1
0	0	5	none	yes	IRR	BOD,SS	no	none	none	0.6	PCL,OXPD	15	1.6	yes		AU-2
0	0	...	none	yes	IRR	none	no	none	none	0.2	PCL,TF	0	0	no		AU-3
...	...	...	...	...	IRR IND	...	...	...	...	1.6	PCL,TF,SCL, POL,CCOAG, SF	...	*	...	*piped throughout city	AF-1
0	0	0	LAB	yes	IRR IND DOM	SS	yes *	LAB	PS	18.	PCL,TF,SCL, SF,POL	0	5.0	yes	*R&D unit producing drinking water	AF-2
4060*	235.3	32	Cl_2	yes	DOM	...	no	AUTO	PS	1.0	PCL,TF,SCL, POL,pH, CCOAG,SF, CADS**	...	8.0	yes	*total cost for blended domestic water; **additional treatment: algae flotation,foam fractionation	AF-3
...	...	...	...	...	IND	SS,BOD	yes *	...	none	5.0	...	5	...	...	*treatment after reuse: SS removal, heavy metals removal	EN-1
32	25.9	5	LAB	yes	IND	PO_4,SS, NH_3	yes *	LAB	PS	8.0	PCL,TF,SCL	none	0.8	yes	*additional treatment: cold lime	IS-1
170	85.0	0	LAB	no	IRR IND	BOD,SS	yes *	LAB	PS	2.5	PS,AS,SCL	2.0	0.5	no	*additional treatment: CCOAG,pH,IE	MX-1

SUPPLEMENTAL SUPPLY	
PrS	Private Source
PS	Public Source
QUALITY SAFEGUARDS	
AUTO	Automatic Testing
PPC	Pre & Post Chlorination
LAB	Regular Lab Testing
ST	State Testing Only
TREATMENT PROCESSES	
-PRIMARY TREATMENT	
PCL	Primary Clarification
RSL	Raw Sewage Lagoon
-SECONDARY TREATMENT	
AS	Activated Sludge
AER	Aeration Only
TF	Trickling Filter
CCOAG	Chemical Coagulation
OXPD	Oxidation Ponds
-TERTIARY TREATMENT	
ANTH	Anthracite Filter
MMF	Mixed Media Filter
SF	Sand Filter
CADS	Carbon Adsorption
CCOAG	Chemical Coagulation
DAER	Deaeration
IE	Ion Exchange
LCOAG	Lime Coagulation
pH	PH Adjustment
POL	Polishing Ponds
RO	Reverse Osmosis

			PRODUCER INFORMATION												
			INFLUENT			AVERAGE CHARACTERISTICS OF EFFLUENT TO REUSE									
QUESTIONNAIRE RESPONSE NUMBER		A5	B1a	B2b	B3	C1a	C1c	C2a	C2b	C2c	C2d	C2e	C2f	C2g	C2h
CODE NUMBER	MUNICIPAL PLANT LOCATION	YEAR REUSE BEGAN	TOTAL AVERAGE VOLUME, MGD	INDUSTRIAL WASTE %	SIGNIFICANT INDUSTRIAL WASTE TYPES	AVERAGE REUSE VOLUME, MGD	SEASON OF MAXIMUM REUSE	BOD, Mg/l	SS, Mg/l	TDS, Mg/l	B, Mg/l	CHLORIDES, Mg/l	pH, Mg/l	COLIFORMS, MPN	HEAVY METAL TYPES
AZ-1	BAGDAD, AZ (Bagdad Copper Corp.)	1967	0.2	0	none	0.2	none	14	100	100	18	12	6.8	...	none
AZ-2	CASA GRANDE, AZ	1959	1.0	...	...	1.0	...	...	...	...	...	...	...	...	...
AZ-3	FLAGSTAFF, AZ	1972	1.0	0	none	1.0	sum	17	30	...	...	...	7.2	...	...
AZ-4	FLORENCE, AZ (Arizona State Prison)	1953	0.7	0	none	0.7	spr sum	55	111	...	...	...	8.0	100,000	none
AZ-5	FT. HUACHUCA, AZ (Ft. Huachuca Mil. Res.)	1941	1.5	0	none	1.0	...	27	...	...	...	...	7.3	...	...
AZ-6	GRAND CANYON, AZ	1928	0.2	7	deterg., NaCl	0.03	spr sum	10	10	616	...	200	7.0	0	...
AZ-7	KEARNY, AZ	1958	0.6	0	none	0.5	...	...	...	...	...	...	...	...	...
AZ-8	LAKE HAVASU, AZ	1972	0.6	0	none	0.6	...	5	0.1	...	...	1	7	...	...
AZ-9	MESA, AZ	1957	4.3	10	none	4.3	...	45	30	...	...	350	7.5	50,000	...
AZ-10	MORENCI, AZ (Phelps Dodge Corp.)	1957	0.6	0	none	0.6	none	...	...	...	...	...	...	...	...
AZ-11	PHOENIX, AZ (23rd Avenue Plant)	1932	40.0	7	plating	28.0	none	20	20	800	...	300	7.5	...	...
AZ-12	PHOENIX, AZ (91st Avenue Plant)	1971	60.0	7	plating	60.0	none	13	25	1000	...	...	7.4	3.5×10^6	...
AZ-13	PRESCOTT, AZ	1958	1.5	0	none	0.5	spr sum	70	117	...	...	...	7.0	...	...
AZ-14	SHONTO, AZ (BIA, Shonto Board. School)	1965	0.1	0	none	0.1	...	35	...	350	...	...	8.7	1400	...
AZ-15	TOLLESON, AZ	1968	1.1	60	meat pack., plating	1.1	...	23	16	2250	...	...	7.0	...	...
AZ-16	WILCOX, AZ	...	0.2	0	none	0.2	...	...	...	...	...	...	...	...	...
AZ-17	WINSLOW, AZ	1958	0.8	0	none	0.5	...	50	...	...	...	...	8.5	...	...
CA-1	ARMONA, CA	1951	0.3	0	none	0.3	...	...	...	...	...	...	...	...	...
CA-2	ARVIN, CA	1952	0.5	0	none	0.5	...	...	...	...	...	...	7.3	...	...
CA-3	AVENAL, CA	...	0.5	0	none	0.5	...	...	...	...	...	...	...	...	...
CA-4	BAKERSFIELD, CA (Plant #1)	1912	3.6	14	dairy, poultry	3.6	...	370	118	630	181	96	7.0	...	...

SYMBOLS

QUALITY MONITORING DEVICES

Cl_2	Cl_2 Residual Analizer
CON	Conductivity Meter
LAB	Laboratory Analysis
pH	pH Analizer
TURB	Turbidimeter

PURPOSE OF REUSE

DOM	Domestic
FISH	Fish Habitation
IND	Industrial
IRR	Irrigation
GRD	Ground Water Recharge
REC	Recreation

END USE QUALITY CRITERIA

BOD	Low BOD Required
B	Low Boron Required
Cl	Low Cl Required
DIS	Disinfection Required
DWQ	Drinking Water Quality
FD	Free of Debris
PO_4	Phosphate Removal
NH_3	Low NH_3 Required
OR	Odor Removal
pH	pH Adjustment Required
SHD	State Health Dept. Stds.
SS	Low SS Required
TDS	Low TDS Required
USPHS	U.S. Public Health Stds.

PRODUCER INFORMATION					USER INFORMATION					MUNICIPAL SEWAGE TREATMENT PLANT DESIGN INFORMATION						
REVENUE (Cost Data Appendix)		SYSTEM RELIABILITY													QUESTIONNAIRE RESPONSE NUMBER	
D7	D8	E1	E2	E3	F6	F7	F9	F10	F8	G5	G6 & 7	G8b	G9	G10		
UNIT CHARGES FOR EFFLUENT $/MG	TOTAL 1971 EFFLUENT SALES $1000	SUBSTANDARD EFFLUENT %	QUALITY MONITORING DEVICES	INTERRUPTION TOLERATION	PURPOSE OF REUSE	END USE QUALITY CRITERIA	ADDITIONAL TREATMENT	QUALITY SAFEGUARDS	SUPPLEMENTAL SUPPLY	DESIGN CAPACITY, MGD	TREATMENT PROCESSES	EFFLUENT STORAGE CAPACITY, MGD	EFFLUENT TRANSPORT DISTANCE, MILES	ALTERNATE DISPOSAL METHOD	COMMENTS	CODE NUMBER
0	0	0	...	yes	IND	none	no	none	PrS	4.0	PCL,AS,SCL	13.0	1.0	yes		AZ-1
7	2.5	...	none	...	IRR	...	no	none	none	8.3	RSL	8.4	...	...		AZ-2
36	13.1	0	none	yes	IRR	SHD	yes	LAB	none	...	...	...	...	...		AZ-3
0	0	0	none	yes	IRR	FD	no	...	PS	2.0	PCL,OXPD	...	0.3	yes		AZ-4
0	0	...	...	...	IRR	...	yes	...	PS	4.0	PCL,TF,SCL	2.5	2.0	...		AZ-5
1000	10.9	2	none	yes	IRR DOM	BOD,SS, DIS	no	none	PS	0.5	AS,SCL,ANTH	0.3	2.0	yes		AZ-6
0	0	...	none	...	IRR	...	no	none	none	1.5	RSL	10.0	0	...		AZ-7
0	0	0	none	no	IRR	FD	no	none	none	...	...	...	...	...		AZ-8
3	4.8	0	none	yes	IRR	none	no	none	none	5.0	PCL,TF,SCL	7.0	0	yes		AZ-9
0	0	0	none	yes	IND	none	no	none	PrS	1.5	PCL,TF	0	2.5	no		AZ-10
0	0	...	...	...	IRR	...	...	...	...	30.	PCL,AS,SCL	...	...	yes		AZ-11
4.30	14.1	0	pH	yes	IRR	SHD	no	none	PS	60.	PCL,AS,SCL	234.	2.0	yes		AZ-12
0	0	90	none	yes	IRR	none	no	none	PS	1.5	PCL,OXPD,SF	0.6	5.0	yes		AZ-13
0	0	...	...	...	IRR	...	no	...	PS	0.1	PCL,OXPD	10.0	1.5	...		AZ-14
0	0	1	LAB	yes	IRR	*	no	none	PS	2.5	TF	...	4.0	...	*no irrig. of directly consumed crops or dairy cattle	AZ-15
1.40	0.1	...	...	...	IRR	...	...	...	...	...	RSL	...	...	...		AZ-16
0	0	...	none	yes	IRR	none	no	none	none	1.8	PCL,OXPD	6.5	1.0	yes		AZ-17
0	0	...	none	...	IRR	none	no	none	PrS	0.3	PCL	...	0	...		CA-1
*	1.1	...	...	yes	IRR	...	no	...	PrS	1.0	PCL	1.0	1.5	...	*user charges: 25% of farm income	CA-2
*	3.0	...	...	...	IRR	...	no	...	none	1.0	PCL,OXPD	...	0	...	*user charges: 20% of farm income	CA-3
0	0	25	...	...	IRR	*	...	...	PrS	5.5	PCL	...	...	...	*no irrig. of directly consumed crops	CA-4

SUPPLEMENTAL SUPPLY	
PrS	Private Source
PS	Public Source
QUALITY SAFEGUARDS	
AUTO	Automatic Testing
PPC	Pre & Post Chlorination
LAB	Regular Lab Testing
ST	State Testing Only
TREATMENT PROCESSES	
-PRIMARY TREATMENT	
PCL	Primary Clarification
RSL	Raw Sewage Lagoon
-SECONDARY TREATMENT	
AS	Activated Sludge
AER	Aeration Only
TF	Trickling Filter
CCOAG	Chemical Coagulation
OXPD	Oxidation Ponds
-TERTIARY TREATMENT	
ANTH	Anthracite Filter
MMF	Mixed Media Filter
SF	Sand Filter
CADS	Carbon Adsorption
CCOAG	Chemical Coagulation
DAER	Deaeration
IE	Ion Exchange
LCOAG	Lime Coagulation
pH	PH Adjustment
POL	Polishing Ponds
RO	Reverse Osmosis

			PRODUCER INFORMATION												
			INFLUENT			AVERAGE CHARACTERISTICS OF EFFLUENT TO REUSE									
QUESTIONNAIRE RESPONSE NUMBER		A5	B1a	B2b	B3	C1a	C1c	C2a	C2b	C2c	C2d	C2e	C2f	C2g	C2h
CODE NUMBER	MUNICIPAL PLANT LOCATION	YEAR REUSE BEGAN	TOTAL AVERAGE VOLUME, MGD	INDUSTRIAL WASTE %	SIGNIFICANT INDUSTRIAL WASTE TYPES	AVERAGE REUSE VOLUME, MGD	SEASON OF MAXIMUM REUSE	BOD, Mg/1	SS, Mg/1	TDS, Mg/1	Na, Mg/1	CHLORIDES, Mg/1	pH, Mg/1	COLIFORMS, MPN	HEAVY METAL TYPES
CA-5	BAKERSFIELD, CA (Plant #2)	1912	8.5	0	none	8.5	...	85	26	324	87.4	49.6	7.4	...	...
CA-6	BAKERSFIELD, CA (Mt. Vernon Co. San. Dist)	1949	3.8	1	cotton, chemical	3.8	win	50	50	425	...	...	7.4	...	...
CA-7	BAKERSFIELD, CA (No. of River San. Dist. #1)	1947	2.3	1	...	2.3	...	50	12	...	...	...	7.5	...	...
CA-8	BURBANK, CA	1967	5.2	25	aircrft. mfg.	2.0	sum	2	2	500	88	82	7.2	10	trace
CA-9	CALABASAS, CA (Las Virgenes MWD)	1965	3.0	10	*	3.0	...	5	2	870	...	...	7.8	2.2	...
CA-10	CALISTOGA, CA	1972	0.2	1	...	0.1	sum	13	61	528	122	141	8.4	12,000	...
CA-11	CAMARILLO, CA	1958	2.3	11	plating, chemical	2.3	none	10	14	900	321	195	7.5	2.2	none
CA-12	CAMARILLO, CA (Camarillo St. Hospital)	1935	0.2	0	none	0.3	...	6	6	0.1	0	283	7.4	2.2	none
CA-13	CHINA LAKE, CA (Naval Weapons Center)	1955	1.6	20	air cond.	0.7	...	7	...	450	110	100	8.4	23	...
CA-14	CHINO, CA	1942	2.4	5	meat	2.4	...	10	12	8	70	70	7.5	2	none
CA-15	CHINO, CA (Calif. Inst. for Men)	1941	0.6	20	laundry	0.5	none	15	15	610	62	40	6.9	...	...
CA-16	COACHELLA, CA (Coachella San. Dist.)	1938	1.0	5	food proc.	0.2	none	20	5	475	...	69	7.2	...	none
CA-17	CORNING, CA	1950	0.3	10	food proc.	0.2	sum	25	49	14	...	...	7.3	...	...
CA-18	CUTLER, CA (Cutler PUD)	1960	0.4	1	none	0.3	...	...	...	...	...	...	...	...	...
CA-19	DELANO, CA	1948	2.7	5	none	2.7	...	70	62	...	...	0	7.0	...	...
CA-20	EARLIMART, CA (Earlimart PUD)	1960	0.3	0	none	0.3	...	...	...	...	...	...	...	...	...
CA-21	EXETER, CA	1955	0.7	10	fruit packing	0.7	...	...	...	...	...	...	...	...	...

SYMBOLS

QUALITY MONITORING DEVICES	
Cl_2	Cl_2 Residual Analizer
CON	Conductivity Meter
LAB	Laboratory Analysis
pH	pH Analizer
TURB	Turbidimeter
PURPOSE OF REUSE	
DOM	Domestic
FISH	Fish Habitation
IND	Industrial
IRR	Irrigation
GRD	Ground Water Recharge
REC	Recreation
END USE QUALITY CRITERIA	
BOD	Low BOD Required
B	Low Boron Required
Cl	Low Cl Required
DIS	Disinfection Required
DWQ	Drinking Water Quality
FD	Free of Debris
PO_4	Phosphate Removal
NH_3	Low NH_3 Required
OR	Odor Removal
pH	pH Adjustment Required
SHD	State Health Dept. Stds.
SS	Low SS Required
TDS	Low TDS Required
USPHS	U.S. Public Health Stds.

PRODUCER INFORMATION					USER INFORMATION					MUNICIPAL SEWAGE TREATMENT PLANT DESIGN INFORMATION						
REVENUE (Cost Data Appendix)		SYSTEM RELIABILITY														
D7	D8	E1	E2	E3	F6	F7	F9	F10	F8	G5	G6 & 7	G8b	G9	G10	QUESTIONNAIRE RESPONSE NUMBER	
UNIT CHARGES FOR EFFLUENT $/MG	TOTAL 1971 EFFLUENT SALES $1000	SUBSTANDARD EFFLUENT %	QUALITY MONITORING DEVICES	INTERRUPTION TOLERATION	PURPOSE OF REUSE	END USE QUALITY CRITERIA	ADDITIONAL TREATMENT	QUALITY SAFEGUARDS	SUPPLEMENTAL SUPPLY	DESIGN CAPACITY, MGD	TREATMENT PROCESSES	EFFLUENT STORAGE CAPACITY, MGD	EFFLUENT TRANSPORT DISTANCE, MILES	ALTERNATE DISPOSAL METHOD	COMMENTS	CODE NUMBER
0	0	25	...	...	IRR	*	...	...	PrS	16.	PCL	...	...	...	*no irrig. of directly consumed crops	CA-5
0	0	30	...	...	IRR	none	no	none	PrS	6.6	PCL,TF,SCL	0	5.0	no		CA-6
0	0	...	...	...	IRR	...	...	...	...	3.0	PCL,TF,SCL	40.0	0.3	...		CA-7
43	31.0	0.5	pH, LAB	yes	IND	*	yes **	LAB PPC	PS	6.0	PCL,AS,SCL	0	1.0	yes	*end use quality: desires low TDS,SS, PO_4^-,NO_3^-, organics **user treatment: shock chlorination, pH adjust., corrosion inhibitor	CA-8
5	5.4	0	Cl_2, TURB	yes	IRR	...	...	...	...	...	AS	...	5.0	...	*industries treat wastes before discharge	CA-9
0	0	98	none	yes	GRD	...	...	...	...	0.4	PCL,OXPD, CCOAG	0	0.5	yes		CA-10
0	0	1	...	no	IRR	SHD	no	LAB	PS	4.8	PCL,AS,SCL, POL,SF	12.0	0.5	yes		CA-11
0	0	0	none	no	IRR	...	no	PPC	none	...	PCL,TF,SCL	1.5	0.3	yes		CA-12
0	0	0	Cl_2	...	IRR	SHD	no	none	none	2.0	PCL,OXPD	30.0	0.5	...		CA-13
0	0	0	Cl_2 CON	yes	IRR	SHD,TDS	no	none	none	3.0	PCL,AS,SCL	20.0	1.0	yes		CA-14
0	0	0	none	yes	IRR	none	no	none	none	1.3	PCL,OXPD	11.0	0.8	no		CA-15
0	0	0	none	yes	IRR	none	no	none	none	1.5	PCL,AS	0	0.1	yes		CA-16
0	0	0	none	yes	IRR	*	no	none	...	0.5	PCL,OXPD**	5.0	0.1	...	*cattle not pastured on disposal fields **reuse from PCL tank only	CA-17
*	...	0	none	yes	IRR	none	no	none	none	1.0	PCL,OXPD,TF	6.5	1.0	no	*user charges: 25% of farm income	CA-18
0	0	30	none	yes	IRR	*	no	none	PS	1.0	PCL,OXPD	1760	0.5	yes	*irrig. of non-edible crops only	CA-19
0	0	...	...	...	IRR GRD	...	no	...	none	0.8	PCL,TF,OXPD	...	0	...		CA-20
4.20	1	...	...	...	IRR	...	no	...	none	0.8	PCL,OXPD	...	0	...		CA-21

SUPPLEMENTAL SUPPLY	
PrS	Private Source
PS	Public Source
QUALITY SAFEGUARDS	
AUTO	Automatic Testing
PPC	Pre & Post Chlorination
LAB	Regular Lab Testing
ST	State Testing Only
TREATMENT PROCESSES	
-PRIMARY TREATMENT	

PCL	Primary Clarification
RSL	Raw Sewage Lagoon
-SECONDARY TREATMENT	
AS	Activated Sludge
AER	Aeration Only
TF	Trickling Filter
CCOAG	Chemical Coagulation
OXPD	Oxidation Ponds
-TERTIARY TREATMENT	
ANTH	Anthracite Filter

MMF	Mixed Media Filter
SF	Sand Filter
CADS	Carbon Adsorption
CCOAG	Chemical Coagulation
DAER	Deaeration
IE	Ion Exchange
LCOAG	Lime Coagulation
pH	PH Adjustment
POL	Polishing Ponds
RO	Reverse Osmosis

QUESTIONNAIRE RESPONSE NUMBER		A5	B1a	B2b	B3	C1a	C1c	C2a	C2b	C2c	C2d	C2e	C2f	C2g	C2h
			PRODUCER INFORMATION												
			INFLUENT			AVERAGE CHARACTERISTICS OF EFFLUENT TO REUSE									
CODE NUMBER	MUNICIPAL PLANT LOCATION	YEAR REUSE BEGAN	TOTAL AVERAGE VOLUME, MGD	INDUSTRIAL WASTE %	SIGNIFICANT INDUSTRIAL WASTE TYPES	AVERAGE REUSE VOLUME, MGD	SEASON OF MAXIMUM REUSE	BOD, Mg/l	SS, Mg/l	TDS, Mg/l	Na, Mg/l	CHLORIDES, Mg/l	pH, Mg/l	COLIFORMS, MPN	HEAVY METAL TYPES
CA-22	FALLBROOK, CA (Fallbrook San. Dist.)	1954	0.7	0	none	0.06	spr sum	43	47	1100	175	215	7.0	1.4×10^6	0
CA-23	FRESNO, CA (Plant #1)	1900	26.0	20	none	3.9	spr sum	60	135	700	140	115	8.4	...	...
CA-24	FRESNO, CA (Plant #2)	1900	12.0	30	wine proc.	1.8	spr sum	60	135	700	140	115	8.4	...	...
CA-25	GEORGE AFB, CA	1963	0.6	0	none	0.5	sum	36	100	150	...	...	7.6	...	Cr
CA-26	GUADALUPE, CA	1952	0.5	0	none	0.5	none	77	72	1670	198	138	7.7	424,000	...
CA-27	GUSTINE, CA	...	2.7	65	none	2.0	...	33	90	1130	292	191	9.0	...	...
CA-28	HANFORD, CA	1901	2.0	10	milk proc.	2.0	none	40	124	...	...	70.9	8.7	...	...
CA-29	HEMET, CA	1965	2.8	1	laundry	1.0	spr sum	30	20	720	145	135	7.3	1.8×10^6	none
CA-30	INDIO, CA (Valley San. Dist.)	1936	3.4	10	fruit proc.	0.3	sum fall	15	40	452	...	100	7.2	2.3	...
CA-31	IRVINE, CA (Irvine Ranch W.D.)	1967	2.8	0	none	2.8	spr sum	13	15	1110	200	160	7.5	2	none
CA-32	IVANHOE, CA (Ivanhoe PUD)	1953	0.3	0	none	0.3	...	200	...	...	...	...	...	...	...
CA-33	KERMAN, CA	1950	0.3	0	none	0.3	...	113	88	600	...	0	6.9	...	...
CA-34	LAGUNA NIGUEL, CA (Moulton Niguel W.D.)	1966	0.4	5	none	0.4	...	25	30	1075	235	180	7.4	2.0	none
CA-35	LEUCADIA, CA (Leucadia Co. W.D.)	1962	0.5	0	...	0.5	...	15	18	...	...	375	7.2	2.2	...
CA-36	LIVERMORE, CA	1967	4.2	17	none	4.2	...	7.3	13	768	131	159	6.7	2.5	...
CA-37	LODI, CA	1968	3.7	11	canning plating	3.7	spr sum	13	17	8.6	10	1.6	7.3	...	...
CA-38	LOS ANGELES, CA (L.A. County San. Dist.-La Canada Plant)	1962	0.1	0	none	0.1	none	13	36	1122	300	196	6.8	10	Zn Fe
CA-39	LOS ANGELES, CA (L.A. County San. Dist.-Lancaster Plant)	1970	4.0	5	none	0.5	sum	3	3	550	150	80	7.6	...	Zn Fe
CA-40	LOS ANGELES, CA (L.A. County San. Dist.-Palmdale Plant)	1964	1.3	8	...	0.7	spr sum fall	50	200	500	120	55	7.8	...	none
CA-41	LOS ANGELES, CA (L.A. County San. Dist.-Pomona Plant)	1928	7.7	5	none	0.7	sum	15	9	564	100	148	7.7	23	...

SYMBOLS

QUALITY MONITORING DEVICES

Cl_2	Cl_2 Residual Analizer
CON	Conductivity Meter
LAB	Laboratory Analysis
pH	pH Analizer
TURB	Turbidimeter

PURPOSE OF REUSE

DOM	Domestic
FISH	Fish Habitation
IND	Industrial
IRR	Irrigation
GRD	Ground Water Recharge
REC	Recreation

END USE QUALITY CRITERIA

BOD	Low BOD Required
B	Low Boron Required
Cl	Low Cl Required
DIS	Disinfection Required
DWQ	Drinking Water Quality
FD	Free of Debris
PO_4	Phosphate Removal
NH_3	Low NH_3 Required
OR	Odor Removal
pH	pH Adjustment Required
SHD	State Health Dept. Stds.
SS	Low SS Required
TDS	Low TDS Required
USPHS	U.S. Public Health Stds.

PRODUCER INFORMATION					USER INFORMATION					MUNICIPAL SEWAGE TREATMENT PLANT DESIGN INFORMATION					QUESTIONNAIRE RESPONSE NUMBER	
REVENUE (Cost Data Appendix)		SYSTEM RELIABILITY														
D7	D8	E1	E2	E3	F6	F7	F9	F10	F8	G5	G6 & 7	G8b	G9	G10		
UNIT CHARGES FOR EFFLUENT $/MG	TOTAL 1971 EFFLUENT SALES $1000	SUBSTANDARD EFFLUENT %	QUALITY MONITORING DEVICES	INTERRUPTION TOLERATION	PURPOSE OF REUSE	END USE QUALITY CRITERIA	ADDITIONAL TREATMENT	QUALITY SAFEGUARDS	SUPPLEMENTAL SUPPLY	DESIGN CAPACITY, MGD	TREATMENT PROCESSES	EFFLUENT STORAGE CAPACITY, MGD	EFFLUENT TRANSPORT DISTANCE, MILES	ALTERNATE DISPOSAL METHOD	COMMENTS	CODE NUMBER
0	0	30	none	no	IRR	SHD	no	none	none	0.6	PCL,TF,AS, SCL	0	1	yes		CA-22
0	0	0	LAB	no	IRR	none	no	none	PS	37	PCL	...	...	no		CA-23
0	0	0	LAB	no	IRR	none	no	none	PS	8	TF,SCL	...	...	no		CA-24
0	0	0	Cl_2	yes	IRR	none	no	none	none	1.5	PCL,TF,SCL	10.2	2	no		CA-25
0	0	0	LAB	yes	IRR	none	no	none	PrS	0.5	RSL	1.0	0.3	no		CA-26
0	0	...	...	...	IRR	...	no	...	none	...	RSL	...	0.1	...		CA-27
0	0	0	none	...	IRR	SHD	no	none	none	2.3	PCL,TF,OXPD	72	0	yes		CA-28
18	4.5	0	CON, LAB	yes	IRR, GRD	SS	no	none	none	2.5	PCL,AS	...	1.0	yes		CA-29
0	0	10	Cl_2	yes	IRR	SS	no	none	PrS	5.0	PCL,AS,SCL	...	...	...		CA-30
120	*	0	CON	yes	IRR	B,TDS, DIS	no	LAB	PS	5.0	PCL,AS,SCL	300	3.5	no	*indirect revenue	CA-31
0	0	...	...	...	IRR	...	no	...	PrS	...	PCL,OXPD	...	0.3	...		CA-32
*	*	0	none	yes	IRR	none	no	none	PrS	0.3	PCL	0	0.3	...	*indirect revenue	CA-33
...	...	90	TURB LAB	yes	IRR	...	no	none	PS	...	AS,SCL,SF	5	1.0	yes		CA-34
0	0	1	CON Cl_2	yes	IRR	TDS,DIS, BOD,SS	no	none	PS	0.8	PCL,TF,SCL	10	1.3	yes		CA-35
0	0	1	none	no	IRR	DIS,BOD, SS	no	none	PrS	5.0	PCL,TF,AER, SCL	...	1.0	yes		CA-36
0	0	0	...	yes	IRR	none	no	none	...	3.5	PCL,AS,SCL	250	0	yes		CA-37
0	0	0	none	yes	IRR	FD,TDS	no	none	PrS	0.2	AS,SCL	0.2	0.2	no		CA-38
0	0	15	TURB Cl_2	yes	IRR REC	near DWQ	no	AUTO	none	4.5	PCL,OXPD, CCOAG,MMF	0	4.0	yes		CA-39
5	0.9	0	none	yes	IRR	SHD,BOD	no	none	PS	3.1	PCL,OXPD	50	2.0	yes		CA-40
22	3.9	0	Cl_2 CON TURB	yes	IRR	SHD	no	none	none	9.6	PCL,AS,SCL	0	2.0	yes		CA-41

SUPPLEMENTAL SUPPLY	
PrS	Private Source
PS	Public Source
QUALITY SAFEGUARDS	
AUTO	Automatic Testing
PPC	Pre & Post Chlorination
LAB	Regular Lab Testing
ST	State Testing Only
TREATMENT PROCESSES	
-PRIMARY TREATMENT	
PCL	Primary Clarification
RSL	Raw Sewage Lagoon
-SECONDARY TREATMENT	
AS	Activated Sludge
AER	Aeration Only
TF	Trickling Filter
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-TERTIARY TREATMENT	
ANTH	Anthracite Filter
MMF	Mixed Media Filter
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CADS	Carbon Adsorption
CCOAG	Chemical Coagulation
DAER	Deaeration
IE	Ion Exchange
LCOAG	Lime Coagulation
pH	PH Adjustment
POL	Polishing Ponds
RO	Reverse Osmosis

			PRODUCER INFORMATION												
			INFLUENT			AVERAGE CHARACTERISTICS OF EFFLUENT TO REUSE									
QUESTIONNAIRE RESPONSE NUMBER		A5	B1a	B2b	B3	C1a	C1c	C2a	C2b	C2c	C2d	C2e	C2f	C2g	C2h
CODE NUMBER	MUNICIPAL PLANT LOCATION	YEAR REUSE BEGAN	TOTAL AVERAGE VOLUME, MGD	INDUSTRIAL WASTE %	SIGNIFICANT INDUSTRIAL WASTE TYPES	AVERAGE REUSE VOLUME, MGD	SEASON OF MAXIMUM REUSE	BOD, Mg/1	SS, Mg/1	TDS, Mg/1	N, Mg/1	CHLORIDES, Mg/1	pH, Mg/1	COLIFORMS, MPN	HEAVY METAL TYPES
CA-42	LOS ANGELES, CA (L.A. County San. Dist.-San Jose Creek Plant)	1972	30.5	20	none	23	none	7	13	687	150	138	8.0	20	Fe Zn Pb
CA-43	LOS ANGELES, CA (L.A. County San. Dist.-Whittier Narrows Plant)	1962	17.1	15	none	16	none	12	13	606	130	99	7.6	240	Zn Pb
CA-44	MARCH AFB, CA (March Plant)	1941	0.4	15	aircrft. maint.	0.4	none	15	12	850	175	160	6.8	...	trace
CA-45	MARCH AFB, CA (West March Plant)	1941	0.3	5	none	0.3	none	15	10	900	220	200	6.8	...	trace
CA-46	McFARLAND, CA	1949	0.3	5	agri. pack.	0.3	...	64	259	438	...	78	6.8	...	...
CA-47	MOJAVE, CA (Mojave PUD)	1945	0.2	0	none	0.2	...	...	...	...	232	139	8.2	...	...
CA-48	OCEANSIDE, CA	1958	4.4	1	plating	0.6	none	7	18	1280	285	303	7.7	43	trace
CA-49	ORANGE COVE, CA	1956	0.4	0	none	0.4	...	...	...	...	...	...	...	...	...
CA-50	PALM SPRINGS, CA	1960	2.7	0	none	1.0	...	12	...	437	...	58	7.1	2400	...
CA-51	PATTERSON, CA	1960	0.02	0	none	0.01	...	33	102	11	...	...	8.2	...	...
CA-52	PLEASANTON, CA	1910	1.3	5	...	1.3	...	40	...	...	...	...	7.4	...	...
CA-53	PORTERVILLE, CA	1952	1.3	0	none	0.7	none	...	...	...	...	...	...	...	...
CA-54	POWAY, CA (Pomerado Co. W.D.)	1972	0.4	0	none	0.05	sum	18	23	1450	...	380	8	120	none
CA-55	SAN BERNARDINO, CA	1962	16	15	none	3.0	sum	13	...	553	85	83	7.4	2	none
CA-56	SAN BRUNO, CA (San Fran. Co. Jail #2)	1932	0.1	0	none	0.1	...	...	...	...	...	...	...	...	...
CA-57	SAN CLEMENTE, CA	1957	2.0	0	none	2.0	...	...	...	...	...	0.2	6.9	2	...
CA-58	SAN DIEGO, CA	1971	0.02	15	plating, elect.	.015	none	7	0	35	7	7	7	0	...
CA-59	SAN DIEGO, CA (Rancho Bernardo Reclamation Plant)	1960	1.3	25	plating	1.3	...	15	20	1000	...	...	7.5	23	Cr Zn Cu
CA-60	SAN FRANCISCO, CA (McQueen STP)	1932	1.0	0	none	0.9	none	10	10	...	...	...	6.9	2.2	...
CA-61	SANTA MARIA, CA (Laguna Co. San. Dist.)	1964	1.3	2	photo	1.3	spr sum fall	27	23	1144	270	217	7.0	724,000	none

SYMBOLS

QUALITY MONITORING DEVICES

Cl_2	Cl_2 Residual Analizer
CON	Conductivity Meter
LAB	Laboratory Analysis
pH	pH Analizer
TURB	Turbidimeter

PURPOSE OF REUSE

DOM	Domestic
FISH	Fish Habitation
IND	Industrial
IPR	Irrigation
GRD	Ground Water Recharge
REC	Recreation

END USE QUALITY CRITERIA

BOD	Low BOD Required
B	Low Boron Required
Cl	Low Cl Required
DIS	Disinfection Required
DWQ	Drinking Water Quality
FD	Free of Debris
PO_4	Phosphate Removal
NH_3	Low NH_3 Required
OR	Odor Removal
pH	pH Adjustment Required
SHD	State Health Dept. Stds.
SS	Low SS Required
TDS	Low TDS Required
USPHS	U.S. Public Health Stds.

PRODUCER INFORMATION					USER INFORMATION					MUNICIPAL SEWAGE TREATMENT PLANT DESIGN INFORMATION					QUESTIONNAIRE RESPONSE NUMBER	
REVENUE (Cost Data Appendix)		SYSTEM RELIABILITY														
D7	D8	E1	E2	E3	F6	F7	F9	F10	F8	G5	G6 & 7	G8b	G9	G10		
UNIT CHARGES FOR EFFLUENT $/MG	TOTAL 1971 EFFLUENT SALES $1000	SUBSTANDARD EFFLUENT %	QUALITY MONITORING DEVICES	INTERRUPTION TOLERATION	PURPOSE OF REUSE	END USE QUALITY CRITERIA	ADDITIONAL TREATMENT	QUALITY SAFEGUARDS	SUPPLEMENTAL SUPPLY	DESIGN CAPACITY, MGD	TREATMENT PROCESSES	EFFLUENT STORAGE CAPACITY, MGD	EFFLUENT TRANSPORT DISTANCE, MILES	ALTERNATE DISPOSAL METHOD	COMMENTS	CODE NUMBER
.15	*	...	Cl_2 CON TURB	yes	GRD	USPHS, SHD	no	CON LAB	PS	37.5	PCL,AS,SCL	0	5.0	yes	*new operation	CA-42
68	395	0	Cl_2 CON	yes	GRD	USPHS, SHD	no	LAB	PS	12.0	PCL,AS,SCL	0	3.0	yes		CA-43
*	*	0	Cl_2 pH	yes	IRR	none	...	...	...	1.0	PCL,TF,SCL	2.4	1.0	no	*$1.00 per year user charge	CA-44
*	*	0	Cl_2 pH	yes	IRR	none	...	...	...	1.2	PCL,TF,SCL	2.7	3.0	no	*$1.00 per year user charge	CA-45
0	0	0	none	yes	IRR	none	no	none	PS	0.3	PCL,TF	...	...	...		CA-46
*	*	0	...	...	IRR	...	no	none	none	...	RSL	...	0	no	*$1.00 per year user charge	CA-47
0	0	...	LAB	...	IRR GRD	SHD,DIS	no	...	none	...	PCL,AS,SCL*	0	5.5	yes	*3 plants in city	CA-48
0	0	...	...	...	IRR	SHD	no	...	none	1.4	PCL,TF	10.0	0	...		CA-49
0	0	...	...	...	IRR	...	no	...	PrS	4.2	TF,OXPD	9.5	0.5	...		CA-50
0	0	0	none	yes	IRR	none	no	none	none	0.5	PCL,OXPD	0	0	...		CA-51
0	0	...	...	...	IRR	...	no	...	none	1.7	PCL,TF,AER, SCL,POL	5	0.5	...		CA-52
0	0	...	...	...	IRR GRD	...	no	...	none	2.0	PCL,AS,SCL	0	0	no		CA-53
0	0	0	none	yes	IRR	SHD	no	ST	none	1.5	PCL,TF,SCL, POL	...	0.3	yes		CA-54
15	3.5	0	Cl_2	yes	IRR	OR,BOD, DIS	no	none	PS	16.	PCL,AS,SCL, CCOAG,SF	1.0	...	yes		CA-55
0	0	...	...	...	IRR	...	no	...	PS	0.1	PCL,AS,SCL	1.0	2.3	...		CA-56
*	...	0	LAB	...	IRR GRD	DWQ	no	none	...	4.0	PCL,AS,SCL, MMF	15	3.5	yes	*user charge: 1/2 potable water cost	CA-57
0	0	...	...	yes	R&D*	TDS	...	...	...	.02	RO	...	...	yes	*experimental boiler feed	CA-58
0	0	...	...	...	IRR	...	no	...	none	1.3	AS,SCL	0.2	2.0	...		CA-59
0	0	2	none	no	IRR	SHD	no	none	PS	...	PCL,AS,SCL	2.0	0	yes		CA-60
0	0	0	...	no	IRR	SHD,BOD, SS	no	none	none	1.4	PCL,TF,SCL, POL	13.	...	no		CA-61

SUPPLEMENTAL SUPPLY
PrS Private Source
PS Public Source
QUALITY SAFEGUARDS
AUTO Automatic Testing
PPC Pre & Post Chlorination
LAB Regular Lab Testing
ST State Testing Only
TREATMENT PROCESSES
-PRIMARY TREATMENT
PCL Primary Clarification
RSL Raw Sewage Lagoon
-SECONDARY TREATMENT
AS Activated Sludge
AER Aeration Only
TF Trickling Filter
CCOAG Chemical Coagulation
OXPD Oxidation Ponds
-TERTIARY TREATMENT
ANTH Anthracite Filter
MMF Mixed Media Filter
SF Sand Filter
CADS Carbon Adsorption
CCOAG Chemical Coagulation
DAER Deaeration
IE Ion Exchange
LCOAG Lime Coagulation
pH PH Adjustment
POL Polishing Ponds
RO Reverse Osmosis

			PRODUCER INFORMATION												
			INFLUENT			AVERAGE CHARACTERISTICS OF EFFLUENT TO REUSE									
QUESTIONNAIRE RESPONSE NUMBER		A5	B1a	B2b	B3	C1a	C1c	C2a	C2b	C2c	C2d	C2e	C2f	C3g	C2h
CODE NUMBER	* MUNICIPAL PLANT LOCATION	YEAR REUSE BEGAN	TOTAL AVERAGE VOLUME, MGD	INDUSTRIAL WASTE %	SIGNIFICANT INDUSTRIAL WASTE TYPES	AVERAGE REUSE VOLUME, MGD	SEASON OF MAXIMUM REUSE	BOD, Mg/l	SS, Mg/l	TDS, Mg/l	Na, Mg/l	CHLORIDES, Mg/l	pH, Mg/l	COLIFORMS, MPN	HEAVY METAL TYPES
CA-62	SANTA ROSA, CA	1967	0.2	0	none	0.2	...	10	...	...	...	...	7.1	2.1	...
CA-63	SANTEE, CA	1961	3.3	1	none	1.0	none	5	9	1168	207	245	7.2	2	...
CA-64	SHAFTER, CA	1938	1.0	0.5	food, meat	1.0	spr sum	54	98	...	...	...	7.0	...	...
CA-65	SOUTH LAKE TAHOE, CA	1966	2.7	0	none	2.7	spr sum	1	0	250	5	30	7.0	2	none
CA-66	STRATHMORE, CA (Strathmore, PUD)	1949	0.2	60	...	0.2	...	...	...	...	...	...	...	...	...
CA-67	SUSANVILLE, CA (Susanville San. Dist.)	1951	0.8	0	...	0.2	sum	40	30	...	...	...	...	50	...
CA-68	TAFT, CA	1951	1.0	...	...	1.0	...	...	...	...	...	...	...	...	...
CA-69	TEHACHAPI, CA	1937	0.5	0	none	0.4	...	120	...	...	...	...	...	...	...
CA-70	THOUSAND OAKS, CA	1968	0.1	0	none	0.1	spr sum fall	1	1	450	124	136	7.7	2.1	none
CA-71	TULARE, CA	1926	3.8	82	dairy proc.	3.8	none	...	...	...	...	...	...	...	...
CA-72	TWENTYNINE PALMS, CA (U.S. Marine Corps)	1954	1.2	0	none	0.5	...	70	...	460	180	40	7.4	0	...
CA-73	VALLEY CENTER, CA (Valley Center MWD)	1965	0.01	0	none	0.01	...	25	...	...	...	...	7.0	...	...
CA-74	VENTURA, CA	1966	5.5	25	fruit proc.	0.3	spr sum	30	30	2000	400	400	7.2	23	...
CA-75	VISALIA, CA	1966	5.1	25	...	5.1	...	40	32	600	...	175	7.5	...	...
CA-76	WASCO, CA (Wasco PUD)	1937	0.8	20	...	0.7	...	150	173	...	...	...	7.0	...	...
CA-77	WEED, CA	1948	0.2	5	none	0.2	...	14	33	6	...	...	...	...	...
CA-78	WOODLAND, CA	1930	4.5	50	veg. proc.	6.0	spr sum	25	...	...	...	...	9.2	...	...
CO-1	AURORA, CO	1969	1.3	1	oil	0.4	spr sum	10	20	900	...	...	7.4	...	...
CO-2	COLORADO SPRINGS, CO	1971	21.0	10	plating, elec.	7.0*	win	8	2	630	50	20	6.9	225	Cu Cr Zn

SYMBOLS

QUALITY MONITORING DEVICES

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SS	Low SS Required
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USPHS	U.S. Public Health Stds.

PRODUCER INFORMATION					USER INFORMATION					MUNICIPAL SEWAGE TREATMENT PLANT DESIGN INFORMATION						
REVENUE (Cost Data Appendix)		SYSTEM RELIABILITY														
D7	D8	E1	E2	E3	F6	F7	F9	F10	F8	G5	G6 & 7	G8b	G9	G10	QUESTIONNAIRE RESPONSE NUMBER	
UNIT CHARGES FOR EFFLUENT $/AF	TOTAL 1971 EFFLUENT SALES $1000	SUBSTANDARD EFFLUENT %	QUALITY MONITORING DEVICES	INTERRUPTION TOLERATION	PURPOSE OF REUSE	END USE QUALITY CRITERIA	ADDITIONAL TREATMENT	QUALITY SAFEGUARDS	SUPPLEMENTAL SUPPLY	DESIGN CAPACITY, MGD	TREATMENT PROCESSES	EFFLUENT STORAGE CAPACITY, MGD	EFFLUENT TRANSPORT DISTANCE, MILES	ALTERNATE DISPOSAL METHOD	COMMENTS	CODE NUMBER
0	0	...	...	...	IRR	...	no	...	none	0.7	AS,SF	3.5	2.0	yes		CA-62
150	0.06	0	LAB	yes	IRR REC	SHD	no	PPC	none	4.0	PCL,AS,SCL	32.0	0.5	yes		CA-63
0	0	...	none	yes	IRR	FD	no	none	PS	1.8	PCL,TF	3	0	...		CA-64
0	0	0	AUTO LAB	yes	IRR REC	DWQ,SHD, USPHS	no	none	none	7.5	PCL,AS,SCL, LCOAG,MMF, CADS,Ammonia Stripping	1000.27		yes		CA-55
0	0	...	...	...	IRR	...	no	...	PS	0.2	PCL,OXPD	4.0	0.1	...		CA-66
0	0	...	...	...	IRR	...	no	...	none	1.2	PCL,OXPD	30.0	0.5	...		CA-67
*	0.75	...	...	...	IRR	...	no	...	PS	...	PCL,TF	0	0.1	yes	*user charge flat fee	CA-68
0	0	0	none	yes	IRR	...	...	...	...	0.5	PCL,TF,OXPD	10.0	0	yes		CA-69
220	6.1	0	LAB	yes	IRR	SHD	no	none	PS	1.5	AS,SCL	3.0	0.8	yes		CA-70
19	25.5	30	LAB	yes	IRR	SHD	no	none	PrS	3	PCL,TF	...	...	...		CA-71
0	0	10	none	yes	IRR	DIS	no	none	PS	2.5	PCL,OXPD	14.0	0	no		CA-72
0	0	...	...	...	IRR	...	...	...	...	.01	PCL,AER	5.0	0.8	...		CA-73
0	0	0	LAB	yes	IRR	SHD	no	none	PS	4.0	PCL,TF,SCL	0	0	yes		CA-74
0	0	...	...	yes	IRR	...	no	none	...	6.2	PCL,TF,OXPD	...	...	...		CA-75
0	0	...	...	...	IRR	...	no	...	PS PrS	1.0	PCL	2.7	2	...		CA-76
0	0	5	none	...	IRR	none	no	none	none	...	...	...	...	...		CA-77
0	0	0	none	yes	IRR	SHD	no	none	none	10.	RSL	426	3.5	yes		CA-78
240	20.5	0	TURB	yes	IRR	...	yes **	...	PS	1.0	AS,SCL,MMF*	10.0	3.7	yes	*micro-floc filtration;**occasional algae control	CO-1
94**	38.0	2	TURB pH LAB	yes	IRR IND	BOD,TDS, PO_4,SS	yes	LAB	PS	13. ***	PS,TF,SCL, LCOAG,MMF, pH,CADS****	3.0	2.0	yes	*IRR-5 mgd,IND-2 mgd R&D;**charges to irrig. only; ***expanded system under const.;**** IRR-MMF only tert.	CO-2

SUPPLEMENTAL SUPPLY	
PrS	Private Source
PS	Public Source
QUALITY SAFEGUARDS	
AUTO	Automatic Testing
PPC	Pre & Post Chlorination
LAB	Regular Lab Testing
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TREATMENT PROCESSES	
-PRIMARY TREATMENT	
PCL	Primary Clarification
RSL	Raw Sewage Lagoon
-SECONDARY TREATMENT	
AS	Activated Sludge
AER	Aeration Only
TF	Trickling Filter
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ANTH	Anthracite Filter
MMF	Mixed Media Filter
SF	Sand Filter
CADS	Carbon Adsorption
CCOAG	Chemical Coagulation
DAER	Deaeration
IE	Ion Exchange
LCOAG	Lime Coagulation
pH	PH Adjustment
POL	Polishing Ponds
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			PRODUCER INFORMATION												
			INFLUENT			AVERAGE CHARACTERISTICS OF EFFLUENT TO REUSE									
QUESTIONNAIRE RESPONSE NUMBER		A5	B1a	B2b	B3	C1a	C1c	C2a	C2b	C2c	C2d	C2e	C2f	C2g	C2h
CODE NUMBER	MUNICIPAL PLANT LOCATION	YEAR REUSE BEGAN	TOTAL AVERAGE VOLUME, MGD	INDUSTRIAL WASTE %	SIGNIFICANT INDUSTRIAL WASTE TYPES	AVERAGE REUSE VOLUME, MGD	SEASON OF MAXIMUM REUSE	BOD, Mg/l	SS, Mg/l	TDS, Mg/l	NH_3, Mg/l	CHLORIDES, Mg/l	pH, Mg/l	COLIFORMS, MPN	HEAVY METAL TYPES
CO-3	COLORADO SPRINGS, CO (U.S. Air Force Academy)	1957	1.5	0	none	1.4	spr sum	20	30	...	...	...	7.1	0.5	none
CO-4	DENVER, CO (Denver Board of Water Commissioners)	1970	150	20	plating	0.1	...	3	0	800	...	...	7.2	5	Pb Zn Mo
CO-5	DENVER, CO (Fitzsimons Gen. Hosp.)	1940	0.5	0	none	0.5	spr sum	25	20	43	100	100	7.2	0	...
CO-6	FT. CARSON, CO	1971	1.7	5	laundry	0.3	spr sum fall	12	17	...	...	...	7.5	...	...
FL-1	COCOA BEACH, FL	1969	2.7	0	none	1.0	none	1	1	...	...	17	7.2	25	none
FL-2	TALLAHASSEE, FL	1966	2.0	0	none	2.0	...	57	16	433	56	65	7.4	...	...
ID-1	BOISE, ID	1971	0.1	10	paint	0.1	spr sum	79	29	...	...	0.5	7.3	...	none
KY-1	OKOLONA, KY (Okolona Sewer Con. Dist)	1971	1.0	0	none	1.0	...	375	120	...	...	...	7.2	...	...
MD-1	BALTIMORE, MD	1942	170.	4	...	120.	...	46	44	450	75	100	7.0	5 x 10^6	Zn Fe
MI-1	BELDING, MI	1972	0.5	10	none	0.05	spr sum	6	8	...	...	125	7.5	0	...
MI-2	MIDLAND, MI	1968	6.0	10	none	6.0	sum	25	25	450	...	250	7.6	1000	none
MO-1	JEFFERSON CITY, MO (Mo. State Park Board)	1972	0.4	0	none	0.04	spr sum	...	...	...	11	...	8.7	...	...
MO-2	LOCKWOOD, MO	1971	0.5	0	none	0.5	spr sum	15	...	...	70	68	8.0	200	...
NE-1	SHELBY, NE	1961	0.05	0	none	*	sum	...	...	...	...	...	...	...	...
NV-1	ELY, NV	1967	1.5	2	...	1.0	...	20	...	...	...	...	...	...	...
NV-2	LAS VEGAS, NV	1958	27.0	0	none	3.8	spr sum	21	18	985	...	...	7.6	...	...
NV-3	LAS VEGAS, NV (Clark Co. San. Dist.)	1962	12.5	0	none	4.3	spr sum fall	19	22	1550	...	330	7.6	...	...
NV-4	WINNEMUCCA, NV	1966	0.4	10	none	0.4	...	20	...	...	...	...	8.5	...	...
NJ-1	VINELAND, NJ (Landis Sewerage Auth.)	1965	3.8	60	...	3.8	...	...	...	...	...	...	...	...	...
NM-1	ARTESIA, NM	1960	0.6	5	...	0.6	...	25	...	...	...	...	7.4	...	...

SYMBOLS

QUALITY MONITORING DEVICES

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REVENUE (Cost Data Appendix)		SYSTEM RELIABILITY														
D7	D8	E1	E2	E3	F6	F7	F9	F10	F8	G5	G6 & 7	G8b	G9	G10	QUESTIONNAIRE RESPONSE NUMBER	
UNIT CHARGES FOR EFFLUENT $/MG	TOTAL 1971 EFFLUENT SALES $1000	SUBSTANDARD EFFLUENT %	QUALITY MONITORING DEVICES	INTERRUPTION TOLERATION	PURPOSE OF REUSE	END USE QUALITY CRITERIA	ADDITIONAL TREATMENT	QUALITY SAFEGUARDS	SUPPLEMENTAL SUPPLY	DESIGN CAPACITY, MGD	TREATMENT PROCESSES	EFFLUENT STORAGE CAPACITY, MGD	EFFLUENT TRANSPORT DISTANCE, MILES	ALTERNATE DISPOSAL METHOD	COMMENTS	CODE NUMBER
0	0	0	pH	yes	IRR REC	OR,DIS, SHD	yes	PPC	PS	2.2	PCL,TF,SCL, AER,AS	128.	6.0	yes		CO-3
0	0	0	...	yes	R&D	DWQ	...	...	...	...	RO,IE,CADS, SF,CCOAG,Nitrogen Rem.	...	...	...		CO-4
0	0	0	none	yes	IRR	none	no	none	none	0.9	PCL,TF,SCL	2.3	0.3	yes		CO-5
0	0	0	LAB	yes	IRR	DIS	no	LAB	PS	3.5	PCL,TF,SCL, MMF*	3.0	3.0	yes	*Micro-Floc filtration	CO-6
0	0	0	none	no	IRR	SHD	no	LAB	none	3.0	AER,SCL,OXPD	...	0.3	yes		FL-1
0	0	...	...	...	IRR	...	no	...	none	2.5	PCL,TF,SCL	5.0	0	...		FL-2
0	0	...	LAB	yes	IRR	SHD,DIS, USPHS	no	none	none	0.5	OXPD,AER, CCOAG,MMF*	0.4	0.5	yes	*Micro-Floc filtration	ID-1
0	0	...	...	...	FISH	...	...	...	...	1.0	RSL,OXPD, AER	1.8	...	...		KY-1
1.33	60	0	...	yes	IND	...	yes *	none	PS	...	PCL,TF,SCL, AS**	75.0	5.0	yes	*sed.,Cl₂,screening; **TF-150 mgd, AS-20 mgd	MD-1
0	0	0	LAB	yes	IRR	DIS	no	none	none	...	RSL	...	0	yes		MI-1
3.33	0	...	none	yes	IND	...	...	...	PS	...	...	...	...	...		MI-2
0	0	0	LAB	yes	IRR	SS,B	no	LAB	none	...	RSL	...	0	...		MO-1
0	0	0	none	yes	IRR	none	no	none	none	...	PCL,TF,OXPD	136	0.5	yes		MO-2
0	0	0	none	yes	IRR	SHD	no	ST	none	.05	RSL	...	0	yes	*irrig. twice during summer	NE-1
0	0	...	...	...	IRR	...	no	...	none	3.0	RSL,AER, OXPD	...	3.0	yes		NV-1
20	42.5	0	LAB Cl_2	no	IRR IND	BOD,SS	yes *	LAB PPC	PS	30	PCL,TF,SCL	0	1.0	yes	*LCOAG at steam plant	NV-2
30	63.9	0	LAB	yes	IRR IND	BOD,SS	yes *	LAB	PS	12	PCL,TF,SCL	6.0	1.5	yes	*LCOAG at steam plant	NV-3
0	0	0	none	yes	IRR	none	no	none	PS	1.5	OXPD,AER	33.0	0	yes		NV-4
0	0	...	...	yes	GRD	...	no	...	none	5.0	...	...	...	...		NJ-1
*	0.5	...	...	...	IRR	...	...	...	...	4.0	...	0	1.5	...	*flat rate annual bid	NM-1

SUPPLEMENTAL SUPPLY

PrS	Private Source
PS	Public Source

QUALITY SAFEGUARDS

AUTO	Automatic Testing
PPC	Pre & Post Chlorination
LAB	Regular Lab Testing
ST	State Testing Only

TREATMENT PROCESSES

-PRIMARY TREATMENT

PCL	Primary Clarification
RSL	Raw Sewage Lagoon

-SECONDARY TREATMENT

AS	Activated Sludge
AER	Aeration Only
TF	Trickling Filter
CCOAG	Chemical Coagulation
OXPD	Oxidation Ponds

-TERTIARY TREATMENT

ANTH	Anthracite Filter
MMF	Mixed Media Filter
SF	Sand Filter
CADS	Carbon Adsorption
CCOAG	Chemical Coagulation
DAER	Deaeration
IE	Ion Exchange
LCOAG	Lime Coagulation
pH	PH Adjustment
POL	Polishing Ponds
RO	Reverse Osmosis

QUESTIONNAIRE RESPONSE NUMBER		A5	B1a	B2b	B3	C1a	C1c	C2a	C2b	C2c	C2d	C2e	C2f	C2g	C2h
			PRODUCER INFORMATION												
			INFLUENT			AVERAGE CHARACTERISTICS OF EFFLUENT TO REUSE									
CODE NUMBER	MUNICIPAL PLANT LOCATION	YEAR REUSE BEGAN	TOTAL AVERAGE VOLUME, MGD	INDUSTRIAL WASTE %	SIGNIFICANT INDUSTRIAL WASTE TYPES	AVERAGE REUSE VOLUME, MGD	SEASON OF MAXIMUM REUSE	BOD, Mg/1	SS, Mg/1	TDS, Mg/1	Nr, Mg/1	CHLORIDES, Mg/1	pH, Mg/1	COLIFORMS, MPN	HEAVY METAL TYPES
NM-2	CLOVIS, NM	1935	4.0	17	meat, milk	4.0	...	...	...	...	...	...	...	...	...
NM-3	DEMING, NM	1941	1.5	0	none	1.5	...	...	...	...	...	...	...	...	...
NM-4	DEXTER, NM	...	...	...	...	...	...	...	...	...	...	...	...	...	...
NM-5	JAL, NM	1951	0.3	0	none	0.3	...	...	...	...	...	...	...	...	...
NM-6	LORDSBURG, NM	1949	0.3	0	none	0.3	...	118	69	1021	...	...	7.6	...	...
NM-7	LOS ALAMOS, NM (Los Alamos Co. Utilities)	1951	0.4	0	none	0.2	spr sum fall	22	...	...	...	...	...	...	...
NM-8	ROSWELL, NM	1948	3.0	18	meat packing	3.0	spr sum	55	26	...	...	...	7.4	...	...
NM-9	RATON, NM	1951	0.5	2	none	0.5	spr sum	16	100	...	...	...	7.2	...	...
NM-10	TUCUMCARI, NM	1951	1.0	0	none	0.1	...	...	...	...	...	...	...	...	...
ND-1	DICKINSON, ND	1958	1.0	5	dairy proc.	0.1	spr sum	42	...	...	...	...	...	...	...
OK-1	ENID, OK	1954	5.0	23	...	2.0	...	21	32	600	...	...	7.4	...	...
OK-2	FREDERICK, OK	1919	0.6	17	...	0.2	...	4.2	...	...	...	148	7.2	...	...
OR-1	HILLSBORO, OR	1941	1.0	30	laundry	2.0	win	59	66	...	...	...	7.1	800	...
PA-1	UNIVERSITY PARK, PA (Penn. State University)	1963	0.5	...	...	0.5	...	...	...	...	...	...	...	...	...
TX-1	ABILENE, TX	1958	8.7	12	...	3.2	...	17	...	750	...	168	7.1	...	Mg
TX-2	AMARILLO, TX	1954	10.0	7	meat, food, laundry	6.3*	spr sum	10	15	1400	300	300	7.7	0	none
TX-3	BIG SPRING, TX	1943	0.5	0	none	0.5	...	35	30	960	...	...	7.0	...	...
TX-4	DENTON, TX	1972	6.0	1	metals, meat	1.5	none	30	38	127	...	70	7.2	16,000	Cr Zn
TX-5	HONDO, TX	1968	0.4	0	none	0.4	...	30	96	...	...	...	8.4	...	...

SYMBOLS

QUALITY MONITORING DEVICES

Cl_2	Cl_2 Residual Analizer
CON	Conductivity Meter
LAB	Laboratory Analysis
pH	pH Analizer
TURB	Turbidimeter

PURPOSE OF REUSE

DOM	Domestic
FISH	Fish Habitation
IND	Industrial
IRR	Irrigation
GRD	Ground Water Recharge
REC	Recreation

END USE QUALITY CRITERIA

BOD	Low BOD Required
B	Low Boron Required
Cl	Low Cl Required
DIS	Disinfection Required
DWQ	Drinking Water Quality
FD	Free of Debris
PO_4	Phosphate Removal
NH_3	Low NH_3 Required
OR	Odor Removal
pH	pH Adjustment Required
SHD	State Health Dept. Stds.
SS	Low SS Required
TDS	Low TDS Required
USPHS	U.S. Public Health Stds.

PRODUCER INFORMATION					USER INFORMATION					MUNICIPAL SEWAGE TREATMENT PLANT DESIGN INFORMATION						
REVENUE (Cost Data Appendix)		SYSTEM RELIABILITY														
D7	D8	E1	E2	E3	F6	F7	F9	F10	F8	G5	G6 & 7	G8b	G9	G10	QUESTIONNAIRE RESPONSE NUMBER	
UNIT CHARGES FOR EFFLUENT $/MG	TOTAL 1971 EFFLUENT SALES $1000	SUBSTANDARD EFFLUENT %	QUALITY MONITORING DEVICES	INTERRUPTION TOLERATION	PURPOSE OF REUSE	END USE QUALITY CRITERIA	ADDITIONAL TREATMENT	QUALITY SAFEGUARDS	SUPPLEMENTAL SUPPLY	DESIGN CAPACITY, MGD	TREATMENT PROCESSES	EFFLUENT STORAGE CAPACITY, MGD	EFFLUENT TRANSPORT DISTANCE, MILES	ALTERNATE DISPOSAL METHOD	COMMENTS	CODE NUMBER
*	1.0	...	...	...	IRR	...	no	...	PS	...	PCL,OXPD	...	0	...	*user charge $1000 per year	NM-2
*	...	...	...	...	IRR	...	no	...	none	2.0	PCL,TF,OXPD	13.0	0.3	...	*flat rate annual bid	NM-3
...	0.2*	...	...	...	IRR	...	...	...	...	...	...	...	...	...	*flat rate	NM-4
*	0.5	...	...	...	IRR	...	...	...	...	0.3	PCL,OXPD	...	3.0	...	*$40 per month flat rate	NM-5
0	0	...	...	...	IRR	...	no	...	none	0.8	OXPD	2.4	2.0	...		NM-6
120	3.4	0	LAB	no	IRR	...	...	...	...	0.8	PCL,TF,SCL	0.5	1.0	...		NM-7
11	7.7	...	...	...	IRR	...	no	...	PS	5.0	PCL,TF,SCL	0	3.0	yes		NM-8
*	0.2	2	none	yes	IRR	...	...	...	...	...	...	...	...	...	*user charge $200 per year	NM-9
0	0	...	...	...	IRR	...	no	...	none	1.0	PCL,TF,SCL	0	0.5	yes		NM-10
0	0	...	...	yes	IRR	none	no	none	PS	0.8	RSL	0	0.2	no		ND-1
7	5.0	...	...	...	IND	...	yes *	LAB	PS	8.5	PCL,AS,SCL	0	2.0	yes	*user treatment: chem. addition	OK-1
0	0	...	...	...	IRR	SHD	no	...	...	...	PCL,AS,SCL	0	1.5	yes		OK-2
0	0	0	none	yes	IRR	SHD	no	none	PrS*	2.0	PCL,AS,SCL	3.7	0.5	yes	*industrial waste water	OR-1
0	0	...	...	yes	R&D	...	...	...	...	4.0	...	...	5.0	yes		PA-1
0	0	...	...	...	IRR	...	...	...	...	12.	PCL,AS,SCL	600	3.0	...		TX-1
**	145	0	LAB	yes	IRR IND	BOD,SS, pH	yes ***	LAB	PS PrS	15.	PCL,AS,SCL	18.0	10.	yes	*ind. use-4.5 mgd; **avg. ind. charge $80-$90 per MG; ***user treatment: LCOAG,Alum. Floc., Clar.,Soft.	TX-2
79*	14.4	1	none	yes	IND	TDS,PO_4, HARD.	yes	LAB	PS	1.4	PCL,AER***	1.0	2.0	yes	*graduated charge; **user treatment: hot lime,hot zeo., DAER,ANTH; ***Hayes aeration	TX-3
80	10.8	67	LAB	yes	IND	SS,PO_4, TDS	yes *	LAB	PS	...	PCL,AS,SCL	10.0	2.0	yes	*user treatment: shock chlorin.,pH adjustment	TX-4
0	0	...	none	yes	IRR	none	no	none	none	0.4	PCL,OXPD	...	...	...		TX-5

SUPPLEMENTAL SUPPLY	
PrS	Private Source
PS	Public Source
QUALITY SAFEGUARDS	
AUTO	Automatic Testing
PPC	Pre & Post Chlorination
LAB	Regular Lab Testing
ST	State Testing Only
TREATMENT PROCESSES	
-PRIMARY TREATMENT	
PCL	Primary Clarification
RSL	Raw Sewage Lagoon
-SECONDARY TREATMENT	
AS	Activated Sludge
AER	Aeration Only
TF	Trickling Filter
CCOAG	Chemical Coagulation
OXPD	Oxidation Ponds
-TERTIARY TREATMENT	
ANTH	Anthracite Filter
MMF	Mixed Media Filter
SF	Sand Filter
CADS	Carbon Adsorption
CCOAG	Chemical Coagulation
DAER	Deaeration
IE	Ion Exchange
LCOAG	Lime Coagulation
pH	PH Adjustment
POL	Polishing Ponds
RO	Reverse Osmosis

			PRODUCER INFORMATION												
			INFLUENT			AVERAGE CHARACTERISTICS OF EFFLUENT TO REUSE									
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TX-6	LUBBOCK, TX	1938	14.2	20	packing, dairy, plating	11.4	...	-65	86	...	...	...	...	...	...
		1938	14.2	20	packing, dairy, plating	2.8	...	18	20	1650	450	460	7.8	...	...
TX-7	McKINNEY, TX	...	0.2	...	...	...	...	11	8	...	...	...	...	...	...
TX-8	MIDLAND, TX	...	4.3	5	packing	4.3	none	250	250	1200	235	305	6.7	...	trace
TX-9	ODESSA, TX	1956	6.5	1	plating	5.5	sum	10	13	1300	...	250	7.4	6×10^5	...
TX-10	REESE AFB, TX	1943	0.3	0	none	0.02	sum	8	...	...	...	...	...	...	...
TX-11	SAN ANGELO, TX	...	4.8	19	packing, dairy	4.8	none	77	...	...	324	428	8.2	...	none
TX-12	UVALDE, TX	1938	0.9	0	none	0.9	none	40	60	...	...	...	7.0	...	...
UT-1	SUNNYSIDE, UT (Kaiser Steel Corp.)	1954	0.1	25	none	0.1	...	9.4	15	...	...	...	7.4	93×10^3	...
WA-1	WALLA WALLA, WA	1929	6.3	10	food proc.	8.3	...	28	14	...	...	...	6.5	...	...
WA-2	WARDEN, WA	1964	1.3	100	food proc.	1.3	spr sum fall	1100	127	...	...	...	9.5	none	...

SYMBOLS

QUALITY MONITORING DEVICES

Cl_2	Cl_2 Residual Analizer
CON	Conductivity Meter
LAB	Laboratory Analysis
pH	pH Analizer
TURB	Turbidimeter

PURPOSE OF REUSE

DOM	Domestic
FISH	Fish Habitation
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IRR	Irrigation
GRD	Ground Water Recharge
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BOD	Low BOD Required
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Cl	Low Cl Required
DIS	Disinfection Required
DWQ	Drinking Water Quality
FD	Free of Debris
PO_4	Phosphate Removal
NH_3	Low NH_3 Required
OR	Odor Removal
pH	pH Adjustment Required
SHD	State Health Dept. Stds.
SS	Low SS Required
TDS	Low TDS Required
USPHS	U.S. Public Health Stds.

PRODUCER INFORMATION					USER INFORMATION					MUNICIPAL SEWAGE TREATMENT PLANT DESIGN INFORMATION						
REVENUE (Cost Data Appendix)		SYSTEM RELIABILITY														
D7	D8	E1	E2	E3	F6	F7	F9	F10	F8	G5	G6 & 7	G8b	G9	G10	QUESTIONNAIRE RESPONSE NUMBER	
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0	0	1	Cl_2	yes	IRR	none	yes *	LAB	PS	12	PCL,TF,SCL	0	3.0	yes	*user treatment: OXPD	TX-6
119	42.7	1	Cl_2	yes	IND	BOD,SS, pH,Cl, PO_4	yes *	LAB	PS	12	PCL,AS,SCL	0	3.0	yes	*user treatment: LCOAG,RO,IE,ANTH, pH adjustment	
...	...	...	...	...	IRR	...	...	...	PS	...	...	2.0	...	...		TX-7
0	0	0	none	yes	IRR	...	no	none	none	6.0	PCL,TF,OXPD	...	...	...		TX-8
125	250*	C	LAB	yes	IND	**	yes ***	LAB	PrS	8.0	PCL,AS,SCL	15.0	0.5	yes	*user pays municipal treat. costs; **high quality for boiler feed; *** LCOAG,pH,ANTH,IE	TX-9
0	0	0	none	yes	IRR	none	no	none	none	...	...	...	...	...		TX-10
0	0	0	none	yes	IRR	none	no	none	none	5.0	PCL,OXPD	130.	0	no		TX-11
0	0	0	none	yes	IRR	...	no	none	none	1.0	PCL,OXPD	2.6	0	no		TX-12
0	0	10	TURB LAB	yes	IRR	SHD	no	ST	none	0.3	PCL,TF,SCL*	...	0.5	yes	*coke-breeze filter	UT-1
0	0	15	Cl_2	yes	IRR	...	no	none	PS	7.5	PCL,TF,SCL	0	1.0	...		WA-1
0	0	25	LAB	yes	IRR	none	no	none	PS	1.5	PCL,OXPD, AER	...	2.0	no		WA-2

SUPPLEMENTAL SUPPLY	
PrS	Private Source
PS	Public Source
QUALITY SAFEGUARDS	
AUTO	Automatic Testing
PPC	Pre & Post Chlorination
LAB	Regular Lab Testing
ST	State Testing Only
TREATMENT PROCESSES	
-PRIMARY TREATMENT	
PCL	Primary Clarification
RSL	Raw Sewage Lagoon
-SECONDARY TREATMENT	
AS	Activated Sludge
AER	Aeration Only
TF	Trickling Filter
CCOAG	Chemical Coagulation
OXPD	Oxidation Ponds
-TERTIARY TREATMENT	
ANTH	Anthracite Filter
MMF	Mixed Media Filter
SF	Sand Filter
CADS	Carbon Adsorption
CCOAG	Chemical Coagulation
DAER	Deaeration
IE	Ion Exchange
LCOAG	Lime Coagulation
pH	PH Adjustment
POL	Polishing Ponds
RO	Reverse Osmosis

APPENDIX C

TEXAS MUNICIPALITIES REPORTED TO PROVIDE EFFLUENT FOR IRRIGATION BUT NOT TABULATED IN APPENDIX B

City	Ave. Flow mgd	City	Ave. Flow mgd
Abernathy	0.13	Fort Stockton	0.90
Amherst	0.08	Fredericksburg	0.001
Anson	0.19	Freer	0.16
Anton	0.04	Friona	0.25
Aspermont	0.10	Fritch	0.40
Benjamine	0.04	Goldthwaite	0.06
Bexar County	0.005	Gorman	0.08
Big Lake	0.15	Graford	0.02
Blanco	0.04	Grand Falls	0.04
Bonham	1.4	Granger	0.70
Barger	0.88	Hale Center	0.13
Brady	0.50	Happy	0.07
Brownfield	0.47	Hart	0.18
Burkburnet	0.65	Holliday	0.13
Burnet	0.14	Honahans	0.90
Castroville	0.04	Idaldo	0.09
Coahoma	0.05	Ingleside	0.001
Coleman	0.51	Johnson City	0.04
Colorado City	0.51	Karnes City	0.12
Comfort	0.002	Kermit	0.83
Crane	0.31	Kerrville	0.001
Crockett County	0.001	Kilgore	0.005
Crosbyton	0.14	Kingsville	0.81
Cross Plains	0.06	La Coste	0.04
Crystal City	1.20	Lamesa	1.13
Dalhart	0.60	Lorenzo	0.08
Del Rio	0.40	Levelland	0.66
Denison	0.15	Littlefield	0.47
Denver City	0.35	Llano	0.28
Devine	0.08	Lyford	0.27
Dimmitt	0.82	Lockney	0.14
Dublin	1.0	McCamey	0.23
Dumas	1.00	McKinley	1.5
Earth	0.09	McLean	0.13
El Dorado	0.09	Marfa	0.23
El Paso	0.45	Mason	0.14
El SA	0.002	Meadow	0.04
Fabens	0.001	Miles	0.02
Falforias	0.35	Monahans	1.00
Falls City	0.02	Morton	0.24
Farwell	0.79	Muleshoe	0.5
Florence	0.046	Munday	0.21
Floydada	0.07	Nordheim	0.01

APPENDIX C (continued)

City	Ave. Flow mgd
O'Donnell	0.07
Orange Grove	0.06
Paducah	0.23
Pearsall	0.23
Pecas	0.33
Perryton	1.0
Petersburg	0.10
Plains	0.09
Poteet	0.19
Premont	0.20
Quitaque	0.04
Ralls	0.20
Rankin	0.20
Raymondville	0.002
Richland Springs	0.025
Rio Grande City	0.10
Roby	0.06
Rochester	0.04
Ropesville	0.03
Roscoe	0.15
Rotan	0.12
Sabinal	0.08
San Saba	0.17
Santa Anna	0.10
Seagraves	0.19
Seminole	0.45
Shallowater	0.08
Silverton	0.09
Slaton	0.40
Snyder	1.50
Sonora	0.22
Spur	0.1
Stanton	0.15
Stockdale	0.18
Stratford	0.16
Sudan	0.098
Sundown	0.07
Sunray	0.20
Sweetwater	0.001
Tahoka	0.18
Taylor	0.20
Uvaloe	0.002
Van Horn	0.13
Wellington	0.19
Whiteface	0.04
Wilson	0.03
Winters	0.80
Yoakum	0.42
Youth City	0.004

CALIFORNIA LOCATIONS REPORTED TO PROVIDE EFFLUENT FOR IRRIGATION BUT NOT TABULATED IN APPENDIX B

City	MGD Reused	Crop Irrigated
Barstow (USMC)	0.14	G
Brentwood	0.14	P
Buttonwillow	0.18	P
CA Conservation Center	0.04	P
CA Medical Facility (Vacaville)	0.36	P
Callan	0.27	L
Camp Pendleton	0.82	G
Carmel San. Dist.	0.14	Artichokes
Chester	0.16	P
Chowchilla	0.68	C, F
Coit Ranch, Inc.	0.03	C, B
Colton	1.23	P
Coalinga	0.68	C, B
Corcoran	0.68	C, P
Devel Vocational Institute	0.05	P
Dinuba	2.33	Plums, grapes
Elsinore	0.30	P
El Toro Marine Base (USMC)	0.96	G
Encinitas San. Dist.	0.47	Flowers
Fowler	0.23	C grapes
Golden Gate Park	0.63	L
Huron	0.27	C, B
La Canada	0.16	G
Lakeport	0.26	P, Walnuts, pears
Lamont	0.08	C
Lemoore	0.36	P, F
Lindsay	0.30	C
Log Cabin Ranch School	0.01	L
Loma Linda University	0.11	P
Madera	2.38	P
Manteca	1.37	F, L
Meadowood	0.01	G
Mendocino State Hospital	0.05	F
Mount Vernon San. Dist.	3.56	C, F
Murphy's San. Dist.	0.05	P
North of River San. Dist.	2.33	C, F
Ontario-Upland	0.96	G
Pacific Union College	0.13	F
Palmdale	1.10	F
Quincy San. Dist.	0.19	P
Rainbow Municipal Water Dist.	0.02	G
Rancho Bernardo	0.41	G, L
Reedley	0.38	Grapes
Ridgecrest Co. San. Dist.	0.58	F
Riverdale	0.14	P, F
Rossmoor Sanitation, Inc.	1.10	G, L
San Francisco Co. Jail #2	0.14	G
San Joaquin General Hosp.	0.27	F
San Luis Obispo	1.10	P
San Pasqual Academy	0.01	G
Sanger	0.93	Walnuts, grapes
Sebastopol	0.14	P
Shastina San. Dist.	0.14	P
Solvang	0.08	P
Stratford	0.003	C, B
Tehachapi State Institute	0.18	F
Terra Bella	0.03	P
Valley San. Dist.	0.30	C
Warner Springs Resort Co.	0.03	G
Winton San. Dist.	0.41	P
Woodlake	0.16	F

Key:
P - pasture
F - fodder
L - landscape
C - cotton
G - golf course
B - barley

APPENDIX C(continued)

ARIZONA MUNICIPALITIES REPORTED TO PROVIDE EFFLUENT FOR IRRIGATION BUT NOT TABULATED IN APPENDIX B

Arizona City
Avondale
Buckeye
Carefree
Chandler
Coolidge
Douglas
Eloy
Gilbert
Litchfield Park
Mesa
Show Low
Tucson

APPENDIX D

FOREIGN REUSE SITES

SITE	USE	VOLUME REUSED
AFRICA		
RHODESIA		
Salisbury	...	...
SOUTH AFRICA		
Cape Town	...	...
Durban, Natal	...	...
Krugersdorp, Transvaal	...	...
Kimberley	...	...
Pietermaritzburg, Natal	...	...
Port Elizabeth	...	...
Randfontein	...	...
Springs, Transvaal	...	...
Vanderbijl Park, Transvaal	...	...
SOUTH WEST AFRICA		
Luderitz	...	...
AUSTRALIA		
VICTORIA		
Ararat	IRR	...
Benalla	IRR	...
Bendigo	IRR	...
Birchip	IRR	...
Charlton	IRR	...
Cobram	IRR	...
Corryong	IRR	...
Dandenong	IRR	...
Dimboola	IRR	...
Donald	IRR	...
Echuca	IRR	...
Eildon	IRR	...
Euroa	IRR	...
Frankston	IRR	...
Horsham	IRR	...
Jeparit	IRR	...
Kyabram	IRR	...
Kyneton	IRR	...
Lang Lang	IRR	...
Maffra	IRR	...
Mansfield	IRR	...
Mooroopna	IRR	...
Morwell	IRR	...
Murtoa	IRR	...
Rochester	IRR	...

SITE	USE	VOLUME REUSED
AUSTRALIA		
VICTORIA (Continued)		
St. Arnaud	IRR	...
Sea Lake	IRR	...
Seymour	IRR	...
Stawell	IRR	...
Swan Hill	IRR	...
Tallangatta	IRR	...
Tatura	IRR	...
Warracknabeal	IRR	...
Wycheproof	IRR	...
Yarrawonga	IRR	...
WESTERN AUSTRALIA		
Belmont (Western Mining Corporation LTD.)	IND	...
Exmouth	IRR	...
Kalgoorlie	IRR	...
Katanning	IRR	...
Kojonup	IRR	...
Merredin	IRR	...
Narrogin	IRR	...
Northam	IRR	...
Perth (Dampier Mining Company LTD.)	IND	...
Perth (Hamersley Iron Pty. LTD.)	IND	...
Perth (Mount Newman Mining Company Pty. LTD.)	IND	...
Port Hedland	IRR	...
Roebourne	IRR	...
Wyalkatchem	IRR	...
SOUTH AUSTRALIA		
Bolivar Sewage Treatment Works	IRR	1.0 mgd
Glenelg Sewage Treatment Works	IRR	0.5 mgd
CANADA		
ONTARIO		
Listowel	IRR	1.0 Imgd
ENGLAND		
Bristol	IND (cooling, process)	5.3 mgd
Derby County	IND (cooling)	0.3 mgd

SITE	USE	VOLUME REUSED
ENGLAND (Continued)		
Dunstable	IND (process)	0.3 mgd
Nottingham	IND (cooling)	0.8 mgd
Nuneaton	IND (cooling	0.2+ mgd
Oldham County	IND (cooling)	1.5 mgd
Scunthorpe	IND (cooling)	0.7 mgd
Sheffield	IND (cooling)	1.0 mgd
Stoke-on-Trent	IND (cooling)	3.2 mgd
ISRAEL		
NORTHERN DISTRICT		
Bet Shean	IRR	600 CuM/D
Hazor	IRR	600 CuM/D
Upper Tiberias	IRR	1,300 CuM/D
Migdal HaEmeq	IRR	1,075 CuM/D
'Afula	IRR	2,100 CuM/D
Qiryat Shemonah	IRR	2,200 CuM/D
HAIFA DISTRICT		
Or Aqiva	IRR	500 CuM/D
Tirat Karmel	IRR	1,850 CuM/D
Karkur	IRR	1,350 CuM/D
'Atlit	FISH	250 CuM/D
Pardes Hanna	FISH	1,000 CuM/D
CENTRAL DISTRICT		
Even Yehuda, Qadima, Tel Mond	IRR	150 CuM/D
Qiryat Ono	IRR	2,000 CuM/D
Herzliyya	IRR	3,750 CuM/D
Yehūd	IRR	1,300 CuM/D
Hod HaSharon	IRR	3,230 CuM/D
Lod	IRR	3,200 CuM/D
Lod Airport	IRR	2,500 CuM/D
Nes Ziyyona	IRR	1,100 CuM/D
Nahariyya	IRR, FISH	7,000 CuM/D
Rosh Ha'Ayin	IRR	1,880 CuM/D
Rishon Le Zion	IRR	4,500 CuM/D
Rehovot	IRR	5,000 CuM/D
Ramla	IRR	3,800 CuM/D
Ramat HaSharon	IRR	2,000 CuM/D
Ra'ananna	IRR	2,000 CuM/D
Be'er Ya'aqov-Zrifin	IRR	1,400 CuM/D

SITE	USE	VOLUME REUSED
ISRAEL (Continued)		
T. A. DISTRICT - DAN REGION		
Bat Yam	IRR	12,500 CuM/D
Holon	IRR	3,000 CuM/D
Ramat Gan	IRR	1,000 CuM/D
JERUSALEM DISTRICT		
Jerusalem	IRR	13,300 CuM/D
Bet Shemesh	IRR	1,000 CuM/D
SOUTHERN DISTRICT		
Elat	IRR	3,150 CuM/D
Ofaqim	IRR	1,050 CuM/D
Ashdod	IRR	3,600 CuM/D
Be'er Sheva	IRR	6,000 CuM/D
Dimona	IRR	2,000 CuM/D
Yavne	IRR	2,500 CuM/D
Yeroham	IRR	1,000 CuM/D
Mizpe Ramon	IRR	150 CuM/D
Qiryat Gat	IRR	2,000 CuM/D
JAPAN		
Kawasaki	IND (cooling)	...
Nagoya	IND (cooling)	...
Osaka	IND (cooling)	...
Tokyo	IND (cooling, process)	...
MEXICO		
MEXICO CITY		
Chapultepec Park	IRR	3.7 mgd
Sports City	IRR	5.3 mgd
San Juan de Aragon	IRR	11.4 mgd
Xochimilco (Floating Gardens of Mexico City)	IRR	...
Federal Commission of Electricity	IND (cooling)	3.4 mgd
GUADALAJARA		
County Club of Guadalajara	IRR	0.7 mgd
MONTERREY		
Celulosa y Derivados, S.A.	IND	...
Aceros Planos, S.A.	IND	...
Papelera Maldonado	IND	...
Agua Industrial de Monterrey S.de U.	IND	...
Federal Commission of Electricity	IND	...

APPENDIX E

PROCEDURE FOR CALCULATING TREATMENT COSTS

1. Establish equivalent January 1972 capital cost of facility by multiplying the original cost by factors for year built (see Table E-1).
2. Calculate annual cost of facility, amortized over 25 years at 5.5% interest, by multiplying the results of Step 1 by 0.07455.
3. Add annual operating costs to the result of Step 2 to obtain total annual plant costs.
4. Determine average annual treatment volume by multiplying average daily influent flow by 365.
5. Divide result of Step 3 by result of Step 4 to determine average treatment cost of effluent in $/MG, including amortized capital investment.
6. Divide only annual operating cost by result of Step 4 to determine average treatment cost of effluent in $/MG, excluding amortized capital investment.

TABLE E-1

SEWAGE TREATMENT PLANT CONSTRUCTION COST INDEX RATIOS: JANUARY 1972/YEAR BUILT*

YEAR	FACTOR
1957	1.75
1958	1.69
1959	1.66
1960	1.64
1961	1.63
1962	1.61
1963	1.58
1964	1.56
1965	1.54
1966	1.48
1967	1.44
1968	1.39
1969	1.30
1970	1.20
1971	1.08
1972	1.00

*Derived from FWPCA, Department of Interior, Dec. 1967, and Treatment Optimization Research Program, Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio

APPENDIX F

CONVERSIONS FROM ENGLISH UNITS TO METRIC UNITS

Customary Units		Multiplier	Metric Units	
Description	Symbol		Symbol	Reciprocal
	Multiply	By	To Get	
Acre	ac	0.4047	ha	2.471
British thermal unit	Btu	1.055	kJ	0.9470
British thermal units per cubic foot	Btu/cu ft	37.30	J/l	0.02681
British thermal units per pound	Btu/lb	2.328	kJ/kg	0.4295
British thermal units per square foot per hour	Btu/sq ft/hr	3.158	J/m^2sec	0.3167
Cubic foot	cu ft	0.02832	m^3	35.31
Cubic foot	cu ft	28.32	l	0.03531
Pounds per thousand cubic feet per day	lb/1000 cu ft/day	0.01602	kg/m^3 day	62.43
Cubic feet per minute	cfm	0.4719	l/sec	2.119
Cubic feet per minute per thousand cubic feet	cfm/1000 cu ft	0.01667	l/m^3 sec	60.00
Cubic feet per second	cfs	0.02832	m^3/sec	35.31
Cubic feet per second per acre	cfs/ac	0.06998	m^3/sec ha	14.29
Cubic inch	cu in.	0.01639	l	61.01
Cubic yard	cu yd	0.7646	m^3	1.308
Fathom	f	1.839	m	0.5467
Foot	ft	0.3048*	m	3.281
Feet per hour	ft/hr	0.08467	mm/sec	11.81
Feet per minute	fpm	0.00508	m/sec	196.8
Foot-pound	ft-lb	1.356	J	0.7375
Gallon	gal	3.785	I	0.2642
Gallons per acre	gal/ac	0.00935	m^3/ha	106.9
Gallons per day per linear foot	gpd/lin ft	0.01242	m^3/m day	80.53
Gallons per day per square foot	gpd/sq ft	0.04074	m^3/m^2 day	24.54
Gallons per minute	gpm	0.06308	l/sec	15.85
Grain	gr	0.06480	g	15.43
Grains per gallon	gr/gal	17.12	mg/l	0.05841
Horsepower	hp	0.7457	kW	1.341
Horsepower-hour	hp-hr	2.684	MJ	0.3725
Inch	in.	25.4*	mm	0.03937
Knot	knot	1.852	km/h	0.5400
Knot	knot	0.5144	m/sec	1.944
Mile	mi	1.609	km	0.6215

Appendix F (Continued)

Customary Units		Multiplier	Metric Units	
Description	Symbol		Symbol	Reciprocal
	Multiply	By	To Get	
Miles per hour	mph	1.609	km/h	0.6215
Million gallons	mil gal	3785.0	m^3	0.0002642
Million gallons per day	mgd	43.81	l/sec	0.02282
Million gallons per day	mgd	0.04381	m^3/sec	22.82
Ounce	oz	28.35	g	0.03527
Pound (force)	lbf	4.448	N	0.2248
Pound (mass)	lb	0.4536	kg	2.205
Pounds per acre	lb/ac	1.121	kg/ha	0.8921
Pounds per cubic foot	lb/cu ft	16.02	kg/m^3	0.06242
Pounds per foot	lb/ft	1.488	kg/m	0.6720
Pounds per horse-power-hour	lb/hp-hr	0.1690	mg/J	5.918
Pounds per square foot	lb/sq ft	4.882	kgf/m^2	0.2048
Pounds per square inch	psi	703.1	kgf/m^2	0.001422
Pounds per square inch	psi	6.895	kN/m^2	0.1450
Square foot	sq ft	0.09290	m^2	10.76
Square inch	sq in.	645.2	mm^2	0.001550
Square mile	sq mi	2.590	km^2	0.3861
Square yard	sq yd	0.8361	m^2	1.196
Ton, short	ton	0.9072	t	1.102
Yard	yd	0.9144*	m	1.094

*Indicates exact conversion factor.

Note: The U.S. gallon is assumed. If the conversion from the Imperial gallon is required, multiply factor by 1.201.

Standard gravity, $g = 9.80665^* \ m/s^2$

$= 32.174 \ ft/s^2$.

APPENDIX G

Form Approved
O.M.B. No.158-S 72012

When completed mail to SCS Engineers, 4014 Long Beach Boulevard,
Long Beach, California 90807

SURVEY OF TREATED MUNICIPAL WASTEWATER REUSE

A. GENERAL INFORMATION

1. Full name of responsible agency producing the treated wastewater: ______________________________

   ____

2. Address: ______________________________

   ____

3. Telephone numbers: Office: ____________________

   Plant: ____________________

4. Name of agency manager: ____________________

   Title: ____________________ Alternate contact for technical information: Name: ____________________

   Title: ______________________________

5. What year did you begin reclaiming treated effluent? 19___

B. RAW SEWAGE INFLUENT INFORMATION

1. Daily influent raw sewage flow volume:
   - a. Average: __________ MGD
   - b. Range: __________ MGD min. to: __________ max.
2. Influent raw sewage type of waste (estimated percentage)
   - a. Municipal: ____________________ %
   - b. Industrial: ____________________ %
3. Specific industrial wastes - list the industrial wastes, if any, which exert a significant effect upon the chemical character of the influent raw sewage: ____________________

   ____

   ____

4. Remarks: Please add any information which indicates that your raw sewage characteristics are different from the normal range of municipal sewage. For example, significant infiltration of saline ground water causing high TDS, etc.

____

____

____

____

C. TREATED WASTEWATER EFFLUENT INFORMATION

1. Volume:

a. To reuse: Average:________MGD

Range:__________MGD min. to______MGD max.

b. To other disposal: Average________MGD

Range:__________MGD min. to______MGD max.

c. If reuse is seasonal describe seasonal variations in volume reused:______________________________

____

2. Quality: Describe, or attach, typical quality characteristics of the treated wastewater for reuse:

a. BOD, ppm:______________________________

b. Suspended solids, ppm:______________________________

c. Total Dissolved Solids, ppm:______________________________

d. Sodium, ppm:______________________________

e. Chlorides, ppm:______________________________

f. pH:______________________________

g. Coliform, MPN:______________________________

h. Heavy metal ions, if significant:______________________________

i. Other significant characteristics, if any, e.g., color, nutrients, etc.: ______________________________
____

D. TREATMENT FACILITY COST INFORMATION (attach budgets or other helpful cost information)

1. Year treatment plant built: 19__ , capacity: _____MGD, Type of treatment:________________(primary, secondary, or tertiary)

2. Original cost: $__________, construction cost only; do not include costs for land, engineering, financing, and administration.

3. Significant additions:

Brief description	Year	Cost

4. Operating cost in 1971, (excluding amortization) total: $_____________

   a. Labor: $_____________

   b. Supplies: $___________

   c. Utilities: $__________

   d. Other: $_____________

5. State your average cost (including capital amortization) per unit volume of water produced for reuse: $__________ per MG.

6. Estimate your average cost (including capital amortization) per unit volume of water treated, if no reuse were practiced: $_________ per MG. In other words, how much would it cost you to treat the same municipal waste sufficiently to meet regulatory agency discharge requirements to disposal other than reuse.

7. What are your charges for reclaimed water sold: $________ MGD. If graduated, explain:__________________________

8. What were your total revenues from sale of reclaimed water in 1971? $_________.

E. SYSTEM RELIABILITY INFORMATION

1. Estimate the percentage of time that the treatment facility does not meet the volume and quality demands of the reclamation use: __________%

2. Briefly describe the quality monitoring safeguards on your reclaimed water, such as chloride residual analyzer, turbidity meter, conductivity meter, etc.:_______________________

3. Indicate how essential to the user is the maintenance of the reclaimed water supply. In other words, can the user tolerate interruptions in his supply or must the reliability be equivalent to that of a municipal water supply?_______

4. Briefly describe your most serious problems in meeting the volume and quality demands of producing reclaimed water for your reuse situation: ____

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Long Beach, California 90807

F. RECLAIMED WATER USER INFORMATION:

The producing agency and the using agency are often the same, or the producing agency may be able to answer all questions in this section, and in such cases the responder is requested to continue furnishing data. If the user is better able to answer these questions then please detach this section and send it to the user for his completion. If there is more than one user, please xerox and send additional copies or advise SCS Engineers to do so.

1. Name of responder to this section: ____________________
2. Full names of the users of the treated wastewater: ______
   ____
3. User address: ____
   ____
4. User telephone number: ______________________________
5. User name of manager: _______________________________
   Title: __________________ Alternate contact for technical information. Name: ______________________
   Title: ____
6. Describe purpose for which treated wastewater is used; i.e., specific reuse application. Be as specific as possible; e.g., if irrigation, designate the specific crops grown:
   ____
   ____
   ____
   ____
   ____

7. Describe the water quality criteria necessary for the specific reuse application. In other words, what physical and chemical characteristic limitations are imposed upon the reclaimed water supply?

8. If other water sources are used for blending or standby supply, briefly describe the source and how it relates to the reclaimed water:

9. Describe additional treatment provided the reclaimed water, if any, by the user:

10. Describe quality safeguards, if any, installed by the user to protect against sub-standard reclaimed water supply:

11. Describe significant problems, if any, encountered by the user as a result of using reclaimed municipal wastewater:

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Long Beach, California 90807

G. DETAILED DESIGN INFORMATION

The producing agency may have the detailed design information requested below and in such cases the responder is requested to continue furnishing data. If not, please detach this section and send it to your design engineer for his completion.

It is the object of this section to obtain general design criteria used in design of the major reclamation plant processes. Emphasis is upon advanced secondary and tertiary treatment units. Primary and conventional secondary treatment processes should be only briefly described. Please attach any reports, diagrams, etc. which will assist in understanding your design:

1. Full name of the design engineer firm: ____________________
____
2. Engineer address: ____________________________________
____
3. Engineer telephone no.: ______________________________
4. Name of responding engineer: __________________________
__________________________ Title: ______________________
5. Design capacity: __________ MGD
6. Briefly describe primary treatment processes. For example, "screening followed by gravity settling" would be sufficient: ____________________________________
____
____
____
____

6. Briefly describe conventional secondary treatment processes, including secondary clarifiers and its important design parameters. Several typical examples follow to guide you.

Example No. 1 - Activated sludge, conventional spiral flow, 6 hour retention, 2000 ppm mixed liquor suspended solids, 30 percent sludge recirculation rate, 600 ft^3 air per lb BOD removed, gravity circular secondary clarifier with overflow rate of 800 gpd per ft^2.

Example No. 2 - Oxidation pond, surface area 25 acres, average depth 5 ft, average retention 25 days, 5 day BOD loading 50 lbs/day/acre.

Example No. 3 - Trickling filter, plastic media, 10 ft deep x 40 ft diameter, 3:1 recirculation ratio, gravity circular secondary clarifier with overflow rate of 600 gpd per ft^2.

7. Describe below your design parameters for advanced secondary or tertiary treatment utilized. This might include chemical coagulation and sedimentation, filtration through sand or other media, microstraining, carbon adsorption, ammonia stripping or anaerobic denitrification, desalting with reverse osmosis, electrodialysis or ion exchange resins,

aerated polishing ponds, and so forth. We are especially interested in obtaining complete information in response to this question. Accompanying reports, diagrams, etc. will be appreciated: ____________________

8. Storage facility for treated water intended for reuse:
   a. Type: ____________________
   b. Capacity: ____________________ MG
   c. Average storage period: ____________________ days
9. Distance between producer and user that reclaimed water is transported for reuse: ____________________ Miles
10. Alternate disposal method if normal reuse is not feasible: ____________________